INTEGRATED LAND USE/AIR QUALITY/WATER QUALITY CONTROL STUDY FOR SONOMA COUNTY, CALIFORNIA

Prepared by

Association of Bay Area Governments

assisted by

Sonoma County Planning Department, Advanced Planning Division
Bay Area Air Pollution Control District
Water Resources Engineers, Inc.
URS Research Corporation

January, 1977

Contract No. 68-01-2648

Project Officers

William Lienesch
John Robson
David Healy

Prepared for

U.S. Environmental Protection Agency
Washington, D.C. 20460

80 09654

Disclaimer Statement

This report has been prepared and reviewed in final form by the Association of Bay Area Governments. It has not as yet been reviewed in final form by EPA for release and should not at this stage be construed to represent Agency policy. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

ACKNOWLEDGEMENTS

The Association of Bay Area Governments' Sonoma Study project team include:

Project Coordinator and Principal Author	Gordon Jacoby
Contributing Authors	Bob Frommer, Steve Goldman, Marcine Martin, Tom Priestley
Principal Report Reviewers	John McKoy, Planning Director, George Hagevik, Assistant Planning Director Eugene Leong, Division Chief for Air and Water Quality Management
Technical Analysts	Nickey Glidden, Dennis Wambem
Cartographer	Karen Graser

Other ABAG staff that provided management direction and reviewed the draft copies of the report were Revan A. F. Tranter, Executive Director; Dean Macris, Associate Executive Director; Robert Goldman, Technical Services Director and Douglas Detling, Assistant to the Public Affairs Director.

Sub-contractors who assisted the study as both contributing authors and technical analysts were:

Sonoma County Advanced Planning Division	Chris Kirschner
Bay Area Air Pollution Control District	Richard Thuillier
Water Resources Engineers, Inc.	Larry Davis, Larry Roesner, Michael Sonnen
URS Research Company	Michael Miller, Jack Jenkins

TABLE OF CONTENTS

FIGURES

FIGURES

TABLES

CHAPTER I - SUMMARY

The purposes of the "Integrated Land Use/Air Quality/Water Quality Control Study for Sonoma County, California" are:

1) to assess the influence of land use controls for attaining air quality objectives on those for attaining water quality objectives and vice versa, giving particular attention to whether the control strategies for either medium is mutually supportive or conflicting;

2) to analyze the impact of urban spatial patterns on air and water quality to determine if any of the elements of spatial pattern -- population and employment size, type of land use, location of land use or development density -- is the dominant characteristic; and

3) to determine the relative effectiveness of other air and water pollution control strategies, such as vehicle emission devices or site design methods for reducing surface runoff water pollution, in achieving and maintaining environmental objectives.

The study can be particularly helpful in assisting governmental agencies preparing water quality management plans under Section 208 of the Federal Water Pollution Control Act Amendments of 1972 (Pl. 92-500) and air quality maintenance plans as required under the Clean Air Act Amendments of 1970 (Pl. 91-604). Its findings and recommendations should be of assistance to agencies involved in preparing the plans by describing methods for assessing the effectiveness of different air or water pollution control strategies and in recommending an organizational framework for intergovernmental cooperation in preparing the plans.

The approach for analyzing the linkages between air and water pollution control strategies included three steps. The first was projecting different population and land use patterns in Sonoma County to the year 2000 to determine their influence on air and water quality. The land use patterns were studied for their influence on water quality during both dry and wt weather. The second step was analyzing the land use and environmental planning process conducted at different jurisdictional levels to determine its influence on land use and the attainment of air and water quality objectives. The third step was examining air and water quality simulations resulting from the various land use alternatives to determine what development patterns or conditions represented the best arrangement for achieving air and water quality objectives and what are the requirements for intergovernmental policy setting and enforcement to achieve those objectives.

As the study progressed, attention focused on the analysis of two somewhat separate forms of land use control:

1) Growth management programs -- the use of alternative land use plans and specific controls to influence the size, location and timing of urban growth in an area and

2) Site specific management techniques -- the use of pollution abatement strategies other than spatial pattern to reduce the potential for air and water contamination created at a specific location or by a particular emission source. The influence of street sweeping, retention storage facilities and increased ground surface capable of absorbing stormwater were measures studied for water quality improvement. The effectiveness of vehicle emission devices was studied as part of the air quality analysis.

STUDY LIMITATIONS

There were a number of study limitations that the reader should understand in reviewing the conclusions and recommendations. Discussed more completely in Chapter II, they will likely be experienced by others preparing similar studies, including those necessary for "208" water quality management plans.

First, there was a lack of sufficient data, including water quality information during rainy periods, to completely calibrate the surface runoff model. Therefore, the surface runoff model was calibrated using existing water quantity, with water quality determined by use of data from other study areas. Second, there was a limited amount of information on the type and nature of contaminants that are washed off the streets during a rainstorm. More extensive information will be required from future research projects to establish precise findings on surface water contaminants. Third, the models used for both air and water pollution did not directly simulate reactive pollutants. For example, the surface runoff model did not make adjustments for certain chemical or hydrological forces in the river that have varying consequences on different contaminants. The air quality analysis did not consider in a detailed manner the chemical or meteorological factors concerned in the creation and distribution of oxidant. Fourth, the present surface runoff models did not precisely simulate the influence of various control measures. This is largely because most of the control measures have not been fully evaluated as to their effectivenss. Therefore, some of the assumptions used in this study will need refinement in future studies when there is greater experience to draw upon. Finally, the present water quality standards relate more to dry rather than wet weather conditions. For example, many of the present standards are set as concentrations whereas one of the greatest problems associated with surface runoff is increased sedimentation that can be better evaluated by a total emission measurement.

Whereas the above limitations require that the study be read with appropriate qualification, any discrepancies between the simulated and the actual data should not be overstated because the purpose of the study is to establish relative rather than absolute differences in the effectiveness of different land use growth patterns or control measures in achieving air and water quality.

CONCLUSIONS

The environmental factors analyzed in the Sonoma Study that contribute to or are involved in the air and water pollution process are both numerous and complex. Natural features such as soil types, rainfall patterns, river widths or topographical characteristics are some of these factors. Population and employment needs, building sizes, subdivision designs and travel patterns are a number of the man-made factors that interact with the natural conditions.

All of these factors are known to have some influence or impact on the amount and distribution of air and water pollution. Yet, the critical issue being addressed in the Sonoma Study is which of these factors are the most important in terms of their influence on pollution and which, therefore, should receive the most attention in preparing solutions to reduce the pollution problem.

The general conclusions reached in the study are: 1) assimilative capacity of air and water basins is a key determinant of future levels of population and employment activities that can be supported within the basins without violating environmental standards; 2) the population and employment size and density are the most critical factors affecting both air and water quality as compared to other variables such as location, land use type or meteorological conditions (excluding reactive air pollutants); and 3) other pollution control approaches such as site specific land management techniques generally have greater influence on air and water quality than variations in spatial configurations or intensity of land use.

The combination of the natural features in an air or water basin, whether hydrological or meteorological, are critical factors in determining the concentration and distribution of pollutants in the basin. The concept of assimilative capacity, defined in this study as violating air and water quality standards, is an excellent mechanism by which planners can measure the influence of differing levels of land use or transportation activites on environmental quality objectives.

The assimilative capacity of a basin may be significantly different for air quality than for water quality. The Petaluma sub-basin, for example, has a relatively high assimilative capacity for water pollutants given the population and employment levels of the different land use alternatives. However, it has a relatively low assimilative capacity for oxidant.

The analysis of spatial pattern characteristics, including population and employment size, density, location and land use type, indicated that only the first two of these variables were particularly significant influences on levels of air and water quality. Other things being equal, the land use alternatives which concentrated population and employment produced the highest localized concentrations of non-reactive air pollutants and water pollutants. For example, the worst case situation for both air and water was the central section of Santa Rosa in the Santa Rosa Centered alternative, which was the largest and most densely populated pattern simulated. In this case the particulate concentrations, carbon monoxide concentrations and the total washoff loads entering nearby streams were the highest amounts of any simulation. Yet, when water pollution was measured on a regional level, in the receiving waters of an entire basin, there is very little

difference between the quality levels produced by the various land use alternatives. When air pollution was measured in terms of population exposure to violations of these air quality standards, the centralized, compact spatial patterns result in far worse conditions.

There were no profound relationships between countywide urban development patterns to achieve air quality objectives on those to achieve water quality objectives. The basic reason was that the hydrologic system and meterological patterns in Sonoma County were essentially unrelated. The water quality in a stream draining one city in the County bears little relationship to the quality in a stream draining another city. On the other hand, some air pollutants are subject to a high degree of transport among cities. Air pollutants are transported not only across water basin boundaries within Sonoma County, but they are also transported to and from other sections of the San Francisco Bay Region. It is this dissimilarity in the characteristics of water basins versus air basins that resulted in the lack of well defined interrelationships.

The analysis indicated that the site design/management control measures provide far more effective means of environmental improvement than their spatial form counterparts. The control measures for water quality control that proved most effective were retention storage and street sweeping. The retention storage simulation resulted in a twelve-fold reduction in peak concentration and total washoff over the original simulation. It was effective because it holds the runoff from the beginning of a storm, when urban pollutant washoff is the greatest. Street sweeping resulted in a pollutant reduction equivalent to the frequency of sweeping (i.e., sweep twice as often prior to potential rain period, cut the runoff pollution in half).

The water quality control measure that did not prove effective in the simulation was the reduction of the amount of impervious surfaces in urban development. This measure resulted in a significantly higher pollutant concentrations. This increase was due to a decrease in the amount of runoff available to dilute the pollutants washing off the land.

The air quality mitigation measure studied in this report was the motor vehicle emission control device requirements. The full implementation of the emission device control program resulted in a 30% to 40% reduction of the existing carbon monoxide levels by the year 2000. The failure to implemented the program resulted in a 100% to 200% increase by the year 2000.

The conclusions reached after review of the governmental structure in California concerned with land use, air quality and water quality were that there are five basic deficiencies in the structure:

1) there is a lack of integration of air and water concerns with other social and economic concerns,

2) there is a lack of integration of either air or water policies among all agencies surveyed,

3) there is minimal participation by local government in state and federal pollution control efforts,

4) there is a lack of consistent review or appeal procedures on land use decisions that can impact air and water quality objectives, and

5) many local government policies relating to environment management are too vague for effective enforcement.

RECOMMENDATIONS

The recommendations that follow relate both to methods of preparing environmental management control strategies and the intergovernmental organization arrangements needed to prepare and enforce those strategies.

General Recommendations

1. Water quality standards for wet weather water quality conditions should be recommended as part of "208" water quality management plans. Such standards have not been developed in the "Basin Plans" prepared under Section 303 of the Federal Water Polltuion Control Act Amendments of 1972. The standards should be expressed in terms of both concentrations and total emissions.

2. Methods for projecting population and employment, including those based on alternative governmental policies, should be consistent for both air and water quality planning. Such consistency is necessary in developing the assessment on the assimilative capacity of an air or water basin.

3. Greater priority should be placed on investigating the costs and benefits of such water quality control methods as street sweeping and the use of retention storage. More information is required on their effectiveness, limitations and methods and costs of implementation. For example, model land use ordinances need to be prepared to guide local planning agencies that want to require retention storage in large scale developments.

Spatial Pattern and Assimilative Capacity Recommendations

1. Assimilative capacity assessment should be an initial first step in an environmental management process. Air and water basins need to be described in terms of their capacity to assimilate or absorb air and water pollutants. Such an assessment is necessary to determine the level of growth that can be accommodated by a basin and that determination should be used in developing growth management mechanisms aimed at fostering particular spatial patterns.

   Assimilative capacity should be described in terms of combined population and employment levels, based on a set of assumptions on the pollution generating potential of these two variables. The assumptions might include wastewater production and sewage treatment needs or vehicle trip volumes. In this manner, population and employment provide a convenient measurement device

against which different land use, transportation and infrastructure strategies can be assessed for achieving an optimum development pattern desired for air and water quality objectives.

2. The assertion that centralized and compact urban development is the best spatial pattern for minimizing all types of air pollution needs some serious qualification. This pattern can produce high levels of localized carbon monoxide and particulate concentrations. Yet, it may be necessary to accept these concentrations as a compromise in achieving a development pattern that best supports a mass transit program aimed, in part, at reducing the use of the automobile. Therefore, greater flexibility in plans for meeting air pollution objectives, particularly those for carbon monoxide and particulates, should be considered if a concentrated pattern of urbanization is desired as part of a long-term strategy. Localized concentrations of CO and particulates may have to be accepted to achieve broader regional objectives.

Intergovernmental Organization Recommendations

1. Air and water quality objectives should be integrated within the comprehensive state planning and budgeting program such that infrastructure planning and budgeting have a common basis.

2. State agencies with development permit granting powers should develop a program for delegation of such powers to local government when local planning policies and enforcement mechanisms provide similar environmental protection. Direct state involvement in local land development decisions should be avoided unless the subject matter is so complex that a specialized form of administrative expertise is required.

3. Regional environmental management plans should provide regional direction to State and Federal objectives and should describe the local government should play in planning and enforcing air and water quality objectives. The direction of local government should be provided by 1) describing the assimilative capacity of the air and water basins in which the cities or counties are located, 2) establishing the levels of land use, transportation and infrastructure requirements based on different population and employment assumptions that can be accommodated by the assimilative capacity and 3) describing environmental performance criteria that reflect acceptable levels of pollutants that can be emitted from a city or county. The performance criteria should be expressed as the amounts of each of the various types of pollutants that can be discharged into the air and water. The primary use of these criteria is to suggest to local government the types of policy actions they would need to take to reduce the impacts of new or existing development.

4. Local government, using the different levels of land use activities based on varied population and employment ranges and performance criteria provided by the regional environmental management plan, would prepare individualized approaches to attain the regional objectives. The local government units would be required to adopt ordinances or other plan implementation measures. To include local government to adopt these measures, greater autonomy in air and water quality control strategies could be delegated to them. Similarly, regional review or permit requirements could be waived when local implementation plans become consistent with regional environmental objectives.

CHAPTER II - INTRODUCTION

BACKGROUND

It is increasingly asserted that land use planning and control provide a supplementary strategy to technological controls in the effort to maintain acceptable levels of environmental quality in metropolitan regions. Both areawide water quality management plans prepared under Section 208 of the 1972 Amendments to the Federal Water Pollution Control Act and air quality maintenance plans prepared under Section 110 of the Clean Air Act are expected to include consideration of land use controls as part of overall environmental management strategies.

Yet, experience from similar limited purpose planning efforts, whether concerned with transportation, flood control or housing, has shown that there are often unanticipated impacts of land use controls when used unilaterally for the improvement of a single environmental or social condition. For example, a regional water quality plan that constrains new development in a built-up city with an inadequate sewage treatment system could result in directing urban growth to newly developing communities with adequate sewage treatment but inadequate public transportation, thereby adding to air quality problems.

The impetus for the "Integrated Land Use/Air Quality/Water Quality Control Study for Sonoma County" came from this recognition that potentially undesired or unanticipated impacts can result from limited purpose planning. Specifically, the purposes of the "Sonoma Study" are:

1) assess the relationship of land use controls designed to meet air quality objectives to those designed to meet water quality objectives and vice versa, giving particular attention to whether the control strategies for either medium are supportive or conflicting;

2) analyze the impact of urban spatial patterns on air and water quality to determine if any of the elements of spatial pattern -- population size, location, density or land use -- is the dominant characteristic; and

3) determine the relative effectiveness of other pollution control strategies, such as vehicle emission devices or site design methods for reducing water pollution for storm water runoff, in achieving and maintaining environmental objectives.

Three related steps were undertaken as part of the study approach. The first was the projection of different population and land use patterns to determine their influence on air and water quality. The pollution measures related to future development patterns included air pollution emission projections based on vehicle kilometers travelled (VKT), projections of point and area source air pollutant emissions from existing and potential land uses, projections of point source wastewater loadings from land uses, and projections of runoff pollutant loadings from area sources related to existing and potential land use patterns.

The second step of the study was an analysis of the land use planning and control process conducted at different governmental levels in California to determine what effect this process has on attaining air and water quality management objectives. The jurisdictions reviewed included State, regional, County, local general purpose units of government and subcounty special purpose districts. As the study progressed, attention focused on the use of two somewhat separate types of land use control:

1) Growth management - the use of alternative land use plans and policies to influence the size, location and timing of urban growth in a region, and

2) Site specific controls - the use of conditions or "mitigating measures" to reduce the potential for air or water pollution being created due to the land use activities that take place at a specific site.

The third and final step was one of examining future land use patterns, with their resultant air and water impacts, and estimating the land use policy decisions required of various jurisdictions to create the predetermined land use patterns. From such an assessment, it was possible to understand both 1) how effective the decisions might be in improving environmental quality and 2) under what circumstances a land use decision aimed at attaining air quality objectives would conflict with a desired water quality objective, or vice versa.

The study is written primarily for policy makers and planners/environmentalists who are making or recommending land use decisions. People working in agencies concerned with air or water quality, including pollution control districts, public health departments, public utility departments, public works departments and flood control agencies will also find the study helpful. Finally, people living in Sonoma County, California will find this study useful in understanding what new urban growth will mean to the future of their county.

Sonoma County as a Case Study

It was decided that the analysis of the land use/air quality/water quality linkages should be conducted as an applied case study. This decision was made because many of the earlier studies on the subject matter were of a more theoretical nature or were not applied directly to assist a county in reshaping its planning policies.

There were three principal reasons Sonoma County was selected for the case study:

1) its present pressures for growth are similar to those in many other counties that are located at the fringe of an expanding metropolitan area. Therefore, the findings of the study may well be transferable to those jurisdictions who hope to avoid some of the air and water problems that have occurred over the past decades due to urban expansion.

2) its Planning Department was in the process of preparing its first countywide General Plan and was anxious to consider air and water quality issues, and

3) it is within a major metropolitan area yet has well distinguished topographic and meteorological characteristics that the environmental impact of urban growth both within and outside the study area can be readily evaluated.

The final section of this Chapter will provide a description of Sonoma County and some of the growth dynamics it is facing.

Study Limitations

As with any case study, the selection of Sonoma County as the site affected the study's structure. Currently, the County does not have significant air and water quality problems. Although it is growing rapidly, there is no city with a population over 65,000 people. Therefore, the magnitude of its present air or water pollution problems are small in comparison to other cities and counties in the San Francisco Bay Region. As an example of the water quality problems the study is not facing, Santa Rosa, the largest city in the County, does not have a sewer system that overflows into the storm drainage system during a heavy rain. From the air quality standpoint, the County has sufficient vehicular travel to justify only one major freeway. Therefore, it was not possible to analyze in the Sonoma Study all of the air or water quality problems that may be of concern to other cities or counties in the San Francisco Bay Region.

Of course, it was because of the limited scope of existing environmental problems and the anticipated pressures for increased population growth that lead to the selection of Sonoma County as the study area. It is the intent of the study that some of the findings may assist the County planners in their efforts of anticipating and planning for future growth so that environmental, economic and social objectives can be met.

Because the study took place in California the discussion of governmental organization is restricted to California jurisdictions or institutions. There may be, therefore, some readers who cannot readily identify with the various governmental bodies that are concerned with air and water quality in California and whose policies or actions may appear unique.

There are five other basic limitations faced in preparing this study. Many of the limitations, particularly those concerned with the water quality analysis, may well have to be faced by other planners or engineers who hope to conduct similar studies. They need to be recognized in reading this study as well as in developing the work plans for similar studies. The five limitations are:

1) lack of water monitoring information -- data were only available on river and stream quantity during and following rainstorms. However, no information was available on water quality during those periods. Therefore, the model is calibrated for water quantity, with pollution loads determined by use of data from other study areas with similar characteristics.

2) lack of detailed information on the type and nature of surface pollutants -- the information on the exact type, amount, particle size and source of surface contaminants has been studied in United States for only the past five years. A number of EPA studies cited in Chapter III have summarized initial research on this subject. Yet, it still must be recognized that this analysis is in its infancy and that much more work is needed to establish precise findings on the nature of surface water contaminants and the effectiveness of control measures to remove such contaminants.

3) lack of present air pollution modeling capability to exactly simulate reactive pollutants. The air pollutants modeled in the study are carbon monoxide (CO), particulate matter (PM), and sulfur dioxide (SO_2). Photochemical oxidant, primarily ozone, is perhaps the air contaminant best known to the public. It is extremely difficult to model because it is formed chemically in the atmosphere when hydrocarbons and nitrogen oxides are mixed in the presence of sunlight. Because no model was readily available for oxidant analysis in Sonoma County, it is impossible to conduct a rigorous analysis of this pollutant. The proportional rollback model, a less sophiscated method of oxidant analysis explained in Chapter V, is used in the study.

   In the surface runoff analysis, the model does not make adjustments for certain chemical or hydrologic forces in the river that have differing consequences on different contaminants. For example, the model does not consider how different contaminants may settle through the sedimentation process. The model also does not consider the chemical reactions of heavy metals when mixed with water in the river.

4) lack of present modeling capability to exactly simulate control measures -- the present surface runoff control measures are in their preliminary stages of development. Therefore, it is difficult to adjust or refine the model to simulate the effectiveness of the measures due to lack of data on levels of performance. For example, retention storage, explained in Chapter VI, is a relatively new pollution control measure whose effectiveness in reducing <u>all</u> the various water pollution contaminants has never been tested through water quality monitoring.

It may be very capable of removing insoluable and large contaminants but have limited effectiveness in removing highly soluable and small contaminants.

Moreover, the present surface runoff models give an approximation of the effect of control measures but cannont give absolute measurements due to the nature of some of the model variables and the manner in which they are mathematically analyzed. For example, street sweeping is simulated in the study assuming a particular rate of sweeping efficiency. Yet the rate of efficiency can vary greatly according to the construction material of the street surface, the design of the curbs and gutters, the type and size of the contaminants and the type of sweeping device. These conditions can be fairly exactly measured but the model must generalize them due to other model variable limitations.

5) lack of standards for wet weather water quality -- the present water quality standards are not specifically set for either dry or wet weather conditions and it must be recognized that such conditions need to be evaluated separately. For example, a particular standard established to provide for healthy swimming conditions in a river could not be applicable during a winter storm period when no one is swimming and surface water runoff can be most damaging. Further, many of the present standards are set as <u>concentrations</u> whereas one of the greatest problems of surface runoff is increased sedimentation that can be better evaluated by a <u>total emissions</u> measurement. Therefore, this study does not relate any of the surface runoff simulation to water quality standards because it would be inappropriate.

To summarize the limitations of this study, particularly as it relates to the water quality simulations, it provides a generalized assessment on the <u>relative</u> effectiveness of different control strategies in reducing contaminants but it was not possible to provide <u>exact</u> water quality measurements that can be reviewed against water quality standards. Whereas the above limitations require that the study be read with appropriate qualification, any discrepancies between the simulated and the actual data should not be overstated because the purpose of the study is to establish <u>relative</u> rather than <u>absolute</u> differences in the effectiveness of different land use growth alternatives or control measures in achieving air and water quality objectives.

<u>Who Participated in the Study?</u>

The five participants in the "Integrated Land Use/Air Quality/Water Quality Control Study" include the Association of Bay Area Governments (ABAG), Sonoma County, represented by the Advanced Planning Division of the Planning Department, the Bay Area Air Pollution Control District (BAAPCD), Water Resources Engineers, Inc. (WRE), and URS Research Company. A general description of each participant and the roles they play in the study is as follows:

- ABAG is the areawide comprehensive planning agency for the San Francisco Bay Area. A voluntary association of local governments of the Bay Area, membership includes 85 of 94 cities and 7 of 9 counties in the Bay Area. Twenty-five special districts, regional agencies and other government agencies are non-voting cooperating members. Serving an area of about 7,000 square miles and nearly 5 million citizens, ABAG is presently developing an Environmental Management Plan, an element of its Regional Comprehensive Plan, which will include surface runoff, air quality maintenance, municipal wastewater, point source, industrial wastewater, non-point sources other than surface runoff, water conservation, reuse and supply and solid waste. ABAG staff provided project leadership, technical contributions, coordinated the study team and wrote the final report.

- The Sonoma County Advanced Planning Division was preparing its first general plan during the period of the study. This general plan incorporates such State mandated elements as land use, circulation, open space, conservation and safety as well as the non-mandated transit, air quality, recreation and bikeway elements.

  For the study, Sonoma County provided 1) population, land use, employment and transportation forecast methods and data, 2) water quality reports including groundwater studies and 3) general liaison on all aspects of the study.

- The Bay Area Air Pollution Control District (BAAPCD) was created by the California Legislature in 1955 as the first regional agency dealing with air pollution in California. Its jurisdiction is limited to policing non-vehicular sources of air pollution within the Bay Area (primarily industrial emissions and open burning). The BAAPCD, working in conjunction with Sonoma County, provided the air quality analysis for some of the alternative land use patterns by using air quality dispersion models.

- WRE is a consulting firm specializing in water resources and water quality management planning. It provided most of the water quality modeling and analysis in the study. This included adjusting various surface water runoff and stream quality models to fit Sonoma conditions and alteration of model variables to test the relative impacts of growth management and site specific land use controls on the water quality in the study area rivers and streams.

- URS, a consulting firm specializing in environmental research and planning, provided the study with air quality modeling and analysis of alternative land use patterns using the BAAPCD diffusion model. They also forecast the future photochemical oxidants by using the proportional rollback model technique.

Sonoma County Setting

Sonoma County is one of the nine counties that constitute the San Francisco Bay region. The County's southern boundary is 17 kilometers (27 miles) from the City of San Francisco and extends along the northern

LOCATION OF SONOMA COUNTY
in the San Francisco Bay Region
Mt St Helena
4344
Santa Rosa
SONOMA
NAPA
Napa
SOLANO
Fairfield
Pt Reyes
San Rafael
Martinez
CONTRA COSTA
SAN FRANCISCO
OAKLAND
ALAMEDA
REDWOOD CITY
SAN MATEO
SAN JOSE
SANTA CLARA
0
20
40
KILOMETERS
STUDY AREA
Healdsburg
Santa Rosa Plain
Santa Rosa
Sebastopol
Rohnert Park
Cotati
Valley of the Moon
Petaluma Valley
Petaluma
Sonoma
0
10
km

FIG. II–1

boundary of Marin County and a portion of San Pablo Bay. The County extends 31 kilometers (50 miles) north to south and varies in width from 18 to 25 kilometers (30 to 40 miles) covering an area of 610 square kilometers (1,579 square miles). It is geographically composed of roughly equal areas of valleys, mountains and rolling hills. Figure II-1 indicates the location of Sonoma County in the San Francisco Bay Region.

The study has focused on growth potential in the Santa Rosa Plain/Petaluma Valley and Valley of the Moon. The Santa Rosa Plain/Petaluma Valley, in which the majority of the County's population lives, lies roughly in the middle of the County between rolling hills on the west and the Sonoma Mountains on the east. The cities of Petaluma, Cotati, Rohnert Park, Santa Rosa and Healdsburg are in this valley with Sebastopol on its western fringe in the foothills. On the south eastern side of the County is the narrow Valley of the Moon, sandwiched between the Sonoma Mountains on the west and the Sonoma/Napa Mountains on the east. The City of Sonoma is located in the southern section and small portions of Santa Rosa extend into the northern section of the Valley of the Moon.

A complex system of rivers and streams drain Sonoma County. The Russian River extends for 40 kilometers (65 miles) through the County, entering from Mendocino County to the north and crossing over to the Pacific Ocean. The major northerly tributaries include Windsor Creek and Mark West Creek. The Laguna de Santa Rosa flows into Mark West Creek. Sonoma Creek and the Petaluma River drain the southern portion of the County into San Pablo Bay.

Sonoma County has a Mediterranean climate. The Pacific High, a major high pressure area over the northern Pacific Ocean, locally affects the directions of prevailing winds, seasonal precipitation, cloud cover, amount of available sunshine and fog conditions. Sonoma County experiences an annual cycle of rainy and dry seasons with three-fourths of the County's rainfall occuring from November through March. Temperature averages 8.3^{o}C (47^{o}F) in January to 13.9^{o}C (67^{o}F) in July.

The 1975 population of Sonoma County was approximately 244,300. The eight major cities and towns are Santa Rosa, Petaluma, Rohnert Park, Cotati, Sonoma, Sebastopol, Healdsburg and Cloverdale. Santa Rosa is the largest city and main commercial center, as well as the County seat. Petaluma is the second largest city and the County's dairy center. Petaluma is also growing as an industrial center as well as a place of residence for commuters who travel to work in counties south and east of the city. Rohnert Park is experiencing rapid development attributable to commuters who take up residence there as well as it being the location of California State University-Sonoma. Immediately adjacent to Rohnert Park is Cotati whose factors for growth are much the same as Rohnert Park's. The town of Sonoma is a historical and resort site. Sebastopol is the location for most of Sonoma's apple industry. Healdsburg and Cloverdale are locations for grapes, prunes, lumber and recreation. Agriculture and wine production are found throughout the valleys of Sonoma County.

The main transportation route in the County is U.S. 101 which connects Sonoma County with Marin County and San Francisco to the south and Mendocino County to the north. It also passes through several of Sonoma County's major cities - Petaluma, Cotati, Rohnert Park, Santa Rosa, Healdsburg and Cloverdale. The major east-west route, Highway 12, runs through Sebastopol to the west and Sonoma to the east of U.S. 101. Water transport in Petaluma is available by barge and some shipping occurs via the Petaluma River and San Pablo Bay. The Russian River is navigable by small craft only.

Present Environmental Conditions

The study area for the air quality analysis (Figure II-2) includes the Santa Rosa Plain/Petaluma Valley and the Valley of the Moon. The boundary line for this study area roughly coincides with the elevation 61 meters (200 feet) above the Santa Rosa Plain. It was defined in this manner for the following reasons: 1) it coincides with the Petaluma/Santa Rosa air basin, an area of generally homogenous dispersion characteristics, (2) ninety percent of the County population resides in this area and (3) future urbanization is expected to occur there.

The study area for the water quality modeling effort consists of two basins - the Laguna de Santa Rosa (Laguna) basin and the Petaluma River basin. These two basins contain most of the urbanized land in Sonoma County and are separated by Meacham Hill, a low divide south of Cotati.

The Laguna basin, a sub-unit of the Russian River basin, includes the watersheds of Windsor Creek, Mark West Creek, Santa Rosa Creek, and the upper Laguna (Copeland Creek). The Laguna drains a major portion of the Santa Rosa Plain, including the cities of Santa Rosa, Rohnert Park, Sebastopol and Cotati. The Laguna empties into Mark West Creek at a point about two miles before its confluence with the Russian River. The Petaluma River drains the southern portion of the Santa Rosa Plain, including the City of Petaluma, and empties into the north end of San Francisco Bay (San Pablo Bay) near the City of Novato. There are no major tributaries in this basin.

Air quality in Sonoma County at the present time is generally good with few violations of federal or state standards. Though the County is part of the San Francisco Bay Area air basin, an area ringed by mountains and subject to frequent temperature inversions, the air quality is considerably better than in the southern and southeastern portions of the basin because: (1) the dominant windflow patterns tend to flush pollutants from the major portion of the County while transporting pollutants in from other areas in the basin and (2) there are no major industrial sources or power plants in the County. Because of the absence of major industrial sources and power plants, particulates and SO_2 are not a significant problem. Petaluma does experience occasional excesses of the State 24-hour standard for suspended particulates. A cement batching plant is the source of a local particulate problem.

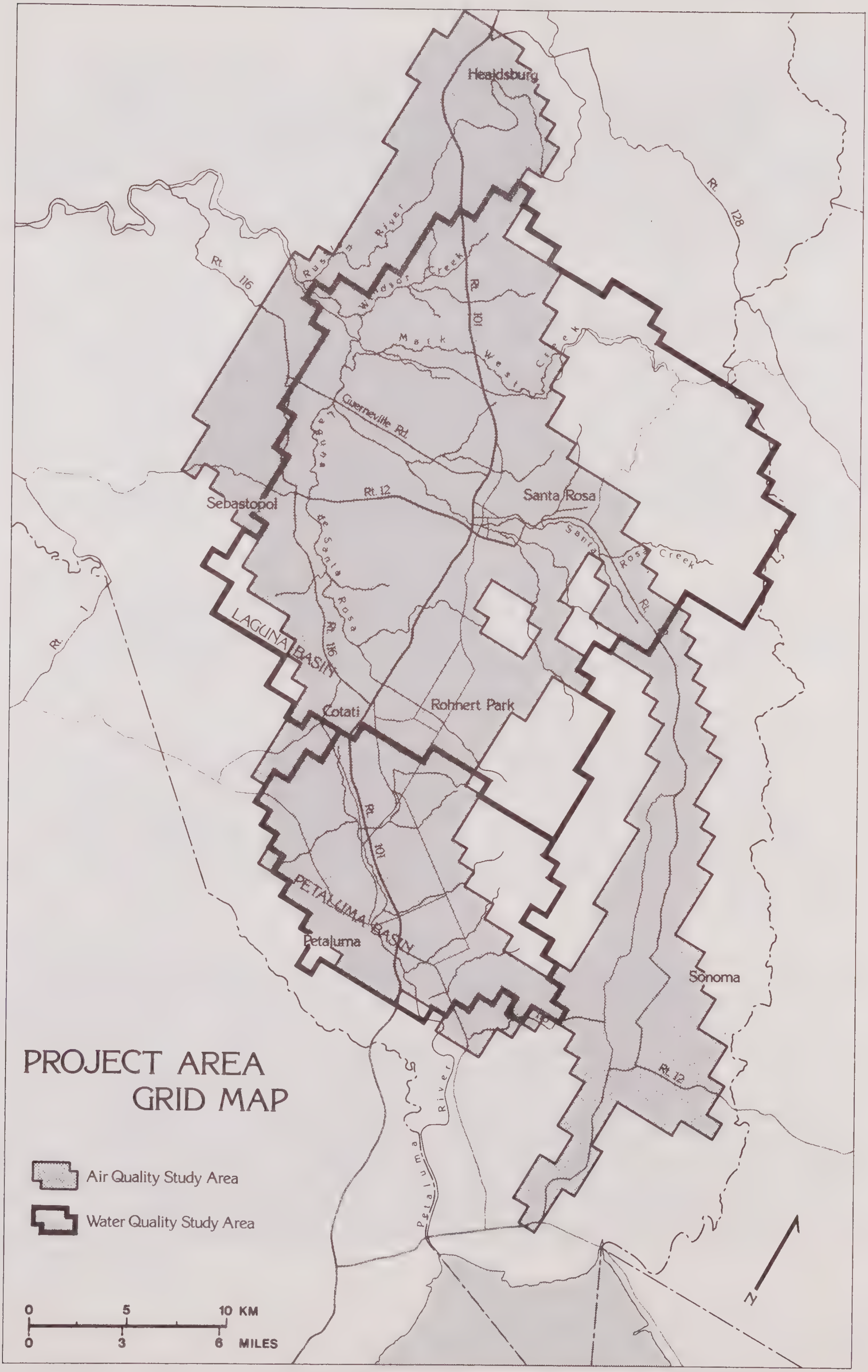

PROJECT AREA
GRID MAP
Air Quality Study Area
Water Quality Study Area
0
5
10 KM
0
3
6 MILES
Healdsburg
Russian River
Windsor Creek
Mark West Creek
Rt. 128
Rt. 116
Rt. 101
Guerneville Rd.
Laguna de Santa Rosa
Rt. 12
Sebastopol
Santa Rosa
Santa Rosa Creek
LAGUNA BASIN
Rt. 1
Cotati
Rohnert Park
PETALUMA BASIN
Petaluma
Sonoma
Petaluma River
N

FIG. II-2

Most of the air pollutant emissions in the County come from automobiles. However, the current air quality situation is difficult to evaluate quantitatively due to the scarcity of monitoring data. The only stations in the County are located in Santa Rosa, Petaluma and the City of Sonoma (begun in late 1974). Santa Rosa and Petaluma have an oxidant problem as evidenced by the federal oxidant standard of 8 parts per hundred million (pphm) being exceeded in Petaluma ten times in 1973 and thirteen times in 1974, and in Santa Rosa, nine times in 1973 and six times in 1974.

Petaluma may experience one to three excesses of the primary federal 8-hour carbon monoxide standard per year in the industrial area east of downtown. The BAAPCD believes that if these excesses do occur, they are due to stationary rather than mobile sources.

Santa Rosa experiences one to three excesses of the carbon monoxide standard in two locations: the downtown and Coddingtown, a major regional shopping center in the northern section of the city. The downtown area, including the interchange of Highways 101 and 12, experiences both large traffic volumes at low speeds (on the surface streets) and large volumes at medium to high speeds during morning and evening peak hours on the freeways. The Coddingtown area, contains three major indirect sources - the Coddingtown shopping center, Santa Rosa Junior College and the County Administration Center, in addition to a heavily travelled stretch of Highway 101.

The quality of the surface waters in Sonoma County is generally very good. Yet, certain problems do exist in both the Russian and Petaluma River basins. Algal blooms have been reported on various stretches of the Russian River from Healdsburg to the mouth. Surveys in the Laguna de Santa Rosa and Santa Rosa Creek have shown coliform values greater than 50,000/100 milliters (ml), which are well in excess of standards set by the North Coast Regional Water Quality Plan for water contact sports. In addition, low dissolved oxygen (DO) levels have been observed in both the Laguna and Santa Rosa Creek, and problems with septic tanks overflowing into surface waters have been documented in the small rural communities, including some on the Russian River.

The high coliform counts and low DO levels in the Laguna de Santa Rosa and the Santa Rosa Creek were apparently caused by dry weather discharges from the sewage treatment plants of Santa Rosa, Rohnert Park and Sebastopol and from dairy operations near these streams. Since the City of Santa Rosa has eliminated its dry weather discharges as part of recent water quality planning and enforcement efforts, the coliform and DO conditions have improved considerably. Because eutrophication in the Russian River has occurred both upstream and downstream from sewage treatment plant discharges, it is felt that this problem is due to non-point sources.

The estuaries of the Petaluma River are known to be eutrophic (nutrient rich) and there have been indications of low DO levels. Data from these areas are scarce. The City of Petaluma's domestic water supply is endangered by the large quantities of dairy wastes that are discharged to the Petaluma River upstream from the City. California's Department of Fish and Game has expressed concern over these discharges.

Growth Dynamics in Sonoma County

Spillover of population from the San Francisco Bay Region is transforming Sonoma County from an essentially rural area to one that is considerably more urbanized. The changes taking place in Sonoma County are generally similar to those experienced by other high amenity rural areas on the periphery of major metropolitan regions. During the last decade the County has experienced major changes in its economic base, its population and the appearance of its physical environment.

Between 1960 and the present, the County's economy has been changed due to: 1) shifts within its agricultural sector, 2) in-migration of persons who commute to the central San Francisco Bay Region and 3) establishment of new institutions, offices, and production facilities.

Changes in employment patterns between 1960 and 1970 are indicative of the economic shifts that have been taking place. During that period, the work force increased by 59% from 46,000 to 73,000. Although there was a general increase in employment, there were absolute declines in employment in agriculture, forestry and fisheries (18%) and the manufacture of non-durable goods (6.2%). The most dramatic employment increases were in professional and related activities (116%) and finance, real estate and insurance (112%). To some extent, these shifts are partly explained by general changes in the nature of the economy including more mechanization in agriculture and manufacturing and an increased need for professional and administrative services. The phenomenal increase in professional, and finance, real estate and insurance activities can be primarily attributed to the location of a number of new employers in Sonoma County. California State University, Sonoma was established near Rohnert Park in the early 1960's and now has approximately 7,000 students and a large staff. In the mid-60's, State Farm Insurance Company moved its northern California headquarters to Santa Rosa and presently employs over 600 people. A new trend emerged around 1968 with a growing number of high technology industries establishing facilities in the County. The advantages for these industries were inexpensive land, a large semi-skilled labor force and environmental amenities necessary to attract and hold managerial and technical personnel. Hewlett-Packard is the largest of the new employers, with 1,000 employees at present, and plans to expand to 4,500 by 1990. Besides these large employers, the County has also been attracting many small manufacturing enterprises.

The commuters who have been settling in the southern portion of the County, have also had an effect on the County's employment statistics. There were 10,000 out-commuters residing in the County in 1970. This number by 1973 had grown 50% to 15,000 (or approximately 20% of the County's work force).

The County's population in 1975 had reached 244,300, an increase of 96,925 (or 65%) over 1960. Most of the increase can be attributed to in-migration. During that period, the County's rate of population growth has increased by 4,000 to 13,000 persons per year. Most of the new population was accommodated in the communities along Highway 101 from Santa Rosa to Petaluma. Table II-1 indicates the population changes experienced by each community.

TABLE II-1

SONOMA COUNTY POPULATION CHANGES: 1960-1975

	POPULATION TOTALS		INCREASE	% CHANGE
	1960	1975		
Cloverdale	2,848	3,520	672	23%
Cotati	1,852	2,760	900	49%
Healdsburg	4,816	6,520	1,434	29%
Petaluma	14,035	32,050	18,015	128%
Rohnert Park	-0-	13,150	13,150	
Santa Rosa	31,027	64,900	33,873	109%
Sebastopol	2,694	4,600	1,906	70%
Sonoma	3,023	5,025	2,002	66%

The population increase has been accompanied by shifts in population composition. The nature of the changes has varied from one part of the County to another. In the central portions of the County where the suburbanization and economic growth has taken place, the population tends to be younger than in 1960. In Petaluma, for example, there was an increase in the percentage of the population in the 5-14 age group, reflecting the influx of young families. The percentage of population 65 and over has decreased in these communities and the median age has shifted downward. In contrast, the more rural parts of the County, away from the urbanizing Santa Rosa/Petaluma corridor, have had only slight increases in young people and major increases in the over-65 population.

Economic development, population increase and suburbanization have all made for visible changes in the County's landscape. The most dramatic change has been increased urban development which has occurred along Highway 101 from Petaluma to Santa Rosa. The development of large tracts of single family housing for suburbanites east of the old city of Petaluma has greatly increased that community's physical size. More than 4,000 residential building permits, most of them single family, were issued between 1964 and 1974.

Santa Rosa's development has been more dramatic and complicated than Petaluma's because it had to accommodate major commercial, office and industrial facilities. To a large extent, Santa Rosa's central business district has been bypassed, with most of the major commercial and industrial development locating on the city's periphery with quick access to the freeway. A new focus of activity has emerged around a freeway interchange two miles north of the old central business district. The County Administration Center, a regional shopping center and an insurance headquarters were all established there on open land in the 1960s and have since been surrounded by a heavy concentration of smaller businesses and offices. Industrial parks established just to the north of this area have accommodated many of the city's new warehouse and industrial facilities. There has also been a significant amount of commercial and industrial development in a three mile long strip paralleling Highway 101 just to the south of the city.

Santa Rosa has experienced a substantially increased volume of residential development. Between 1964 and 1974, building permits for over 11,000 dwelling units were issued. About a third of these permits were for multi-family units. Much of the residential development during the last 15 years has taken place in the small valleys to the east of the city. In more recent years, there has been increasing development on the plain to the west.

One of the most dramatic changes in the County's landscape has been the appearance of a new community halfway between Santa Rosa and Petaluma. In 1963, large parcels of agricultural land to the east and north of Cotati were incorporated as the City of Rohnert Park. The city now has almost 4,000 acres within its jurisdiction and since its founding has issued building permits for approximately 2,500 dwelling units. In more recent years the city has also managed to attract growing amounts of industrial and commercial activity. The City of Cotati, in contrast, has experienced only modest growth.

Away from the Petaluma/Santa Rosa corridor, urbanization has been more incremental in nature. Sonoma, Sebastopol, Healdsburg, Cloverdale and the unincorporated communities have experienced some infilling and some development of small subdivisions on their fringes. In most cases, the amount of growth has not been large, especially when contrasted to that of the U.S 101 corridor communities.

Historically, there have always been a great many small rural holdings in Sonoma County used for specialized family farming operations. More recently, many of these small farms have been split into 1 to 10 acre parcels and sold as ranchette sites for rural residential living. Typically, ranchettes are developed with single family houses served by wells and septic tanks. Often, they serve as home to people with city jobs but who enjoy gardening, keeping animals, or other activities which require ample space or a rural setting. In some areas of the County, dense concentrations of ranchettes have emerged and strained the groundwater supply, the ability of the soil to absorb septic wastes, and the capacity of the old rural road network to handle the increased traffic.

Sonoma County's rapid growth and change have been accompanied by a number of problems. They include: 1) strained capability of municipalities and special districts to provide services; 2) traffic congestion in some areas; 3) perceptibly reduced air quality; 4) diminished viability of some forms of agriculture; and 5) erosion of what many people feel is the rural and small town character that made Sonoma County attractive in the first place. As the problems have emerged, and the awareness of them has crystallized, the local governments have attempted to exert more control over new development in order to reduce its detrimental effects. The best known of these efforts has been Petaluma's Residential Development Control System, a measure adopted in 1972 that limits the total number of dwelling units that can be built in any one year and establishes a procedure for choosing between the various residential development projects that might be proposed. During the past year, Santa Rosa has also adopted a growth management program that brings together annexation and urban extension policies and coordinates them with the city's overall urban development goals. The County has begun to strengthen some of its develop-

ment control mechanisms -- revising its zoning ordinance, rezoning those areas of the County that are under most severe development pressure, and greatly restricting the use of the lot-split mechanism that had facilitated the proliferation of small rural lots.

In spite of the efforts made to date, the County's development has yet to be entirely brought under effective control. One persistent barrier to successful growth management has been the lack of consensus among the muncipalities, the County and the various special service districts as to the objectives to be achieved. Consequently, the actions of one governmental unit often run counter to the actions or desires of another. An example is the conflict between the orderly expansion of the municipalities and the urban and semi-urban development which the County has allowed on their borders. The problem is intensified by the existence of special service districts which permit an urban level of development without annexation. The County's general plan program, which is now nearing completion, has placed the growth problems in perspective, and has outlined some common goals. Yet, intergovernmental mechanisms to ensure that these goals are achieved have yet to be worked out.

It is, therefore, these growth issues, and the potential air and water problems they can create, that provided the rationale for selecting Sonoma County as a case study for determining the linkages between land use/air quality/water quality controls.

CHAPTER III - PRESENT THEORIES ON INTERRELATIONSHIPS OF AIR AND WATER QUALITY AND LAND USE

The growing awareness among planners and policy makers of the relationships between air and water quality and the use of land can best be measured in terms of the increased volume of literature on the subject. The interrelationships that have traditionally received the greatest attention have to do with meteorologic and hydrologic factors considered in locating industries or sewage treatment plants, the influence of alternative spatial patterns on the generation and dispersion of pollutants, and the role of vegetation and open space in reducing pollution.

Many of the initial theories about the air and water quality relationship to urban development were highly speculative or based on limited research. In retrospect, many of the early notions were somewhat simplistic and failed to provide an adequate basis for sound decision making.

Heightened environmental awareness and the mandates of national and state environmental legislation generated a need for more sophisticated and operationally useful understanding of air and water quality relationships. In response to this need, federal funding has spawned a new generation of environmental research. This chapter provides a survey of recent studies with the intent of providing a background on the various land use/air quality/water quality relationships explored in this study.

This review starts with a bibliographic essay on the rationale for relating land use planning to air and water quality management. Next, the land use control strategies for air and water quality are grouped into the categories of 1) growth management measures to achieve a defined spatial pattern and 2) site specific measures that can be applied irrespective of spatial patterns. The first category discusses the air and water relationships from a regional perspective. These studies typically examine the relationship between urban spatial form and environmental quality. The second category focuses on the smaller-scale subregional or site specific considerations including the influences of urban roadway design and maintenance, runoff control measures for various types of development and local development control ordinance changes for reducing air or water pollution. Finally, the influence of sewer system extensions on land development is discussed because of the importance being placed on this form of growth control by federal, state and regional agencies.

RATIONALE FOR STUDYING INTERRELATIONSHIPS OF AIR AND WATER QUALITY AND LAND USE

There is a growing realization that technological change and operational controls over sources of air and water pollution may not be sufficient to achieve desired air and water quality goals. Land use policies are being looked to as a necessary means of supplementing source controls. For example, it is argued that land use planning and control can be used to prevent excessive concentration of air pollutants, to aid pollution dispersion and to reduce the number of people exposed to high pollutant

levels. Similarly, there is a growing awareness that water quality is affected by stormwater runoff from urban lands and mitigation of stormwater impacts may require some special land use controls.

Other forms of air and water controls may also have indirect land use impacts. For example, a metropolitan transportation control strategy for reducing the amount of automobile travel could redirect the development of new housing, employment and commercial facilities to areas with the best public transportation access. Effluent discharge regulations could influence the distribution of industrial activities due to production shifting to new plants to meet discharge requirements.

Much of the recent national environmental legislation has recognized the influence of air and water controls on land use. EPA Authority Affecting Land Use (Bosselman, Feurer and Callies, 1974) provides a thorough listing of the potential land use impacts of environmental controls. The work gives special attention to the provisions of the Clean Air Act and the Federal Water Pollution Control Act as amended that directly or indirectly affect land use.

The National Environmental Policy Act of 1969 and the 1970 Federal Aid Highway Act also reinforce the momentum for consciously considering the relationships between land use and air and water quality. The National Environmental Policy Act requires the preparation of environmental impact statements for federally funded actions with a significant effect on the environment including considerations of air, water, and land use. The Federal Aid Highway Act requires the issuance of guidelines to ensure that new highways built with Federal aid are consistent with a state implementation plan (SIP) required under the Clean Air Act. A Guide for Reducing Air Pollution Through Urban Planning (Alan M. Voorhees and Assoc., and Ryckman, Edgerly, and Tomlinson and Assoc., 1971) has a discussion on some of the specific legislation mandating coordination of air quality concerns with land use.

The emphasis of the environmental legislation on interrelating land use, air and water considerations suggests a need to work out procedures to integrate these factors into comprehensive planning at the regional and even local level. A strong case for efforts in this direction is made in Promoting Environmental Quality through Urban Planning and Controls (Kaiser et al., 1974).

The literature on air quality planning has given greater attention to the need for integration with land use than literature on water quality. One of the first of reports making such a plea was one which analyzed a local area plan in Los Angeles, Research Investigation, Air Pollution and City Planning, Case Study of a Los Angeles District Plan, (Branch and Leong, 1972). The report demonstrated the inadequacy of conventional land use planning efforts in addressing air quality concerns. The report entitled Air Quality Management and Land Use Planning (Hagevik, Mandelker, and Brail, 1974) indicated a number of methods by which air quality issues could be dealt with in local planning including performance standards and spacing controls in the zoning ordinances.

A number of reports have made observations as to why urban planning had given only limited attention to air quality. The previously mentioned Guide for Reducing Air Pollution Through Urban Planning felt the reasons were:

1. Lack of knowledge of how the arrangement, design and operation of urban land uses affect air quality.

2. Lack of procedures for incorporating air quality considerations into the land use decision-making process.

3. Lack of land use implementation tools with the breadth and depth necessary to affect air quality.

Interagency Cooperation in Comprehensive Urban Planning and Air Quality Maintenance, a nationwide survey carried out by Argonne National Laboratory and the American Society of Planning Officials (1974) cited the lack of adequate information and the scarcity of personnel with appropriate capabilities as the most serious limitations to integrating air quality considerations into the planning process. Although these observations were made in reference to the incorporation of air pollution concerns in the local land use planning process, they can to a large degree be extended to describe the treatment of water quality issues at the local level as well.

Finally, the literature search did not turn up one report that has examined the extent to which the interrelationships between local land use measures designed to improve water quality and those improving air quality conflict with or reinforce each other.

SPATIAL PATTERN VERSUS SITE SPECIFIC/MANAGEMENT CONTROL STRATEGIES

A fundamental environmental management issue that emerged from the review of literature is whether a growth management strategy to achieve an optimum spatial pattern for air and water quality is more effective than the application of site specific management devices or other control methods that are applied with little regard to questions of spatial form.

The question on the effectiveness of planning to achieve an optimum land use pattern raises another series of questions as to which of the characteristics of spatial pattern are instrumental in bringing about the desired levels of air and water quality. Are such factors as population size, geographic location or density the key determinants of the optimal pattern? Which of the characteristics are most necessary in supporting specific work/residence/shopping spatial relationships or for maximizing public transit use?

The current literature does not evaluate the two different strategies in terms of their effectiveness. Yet, an evaluation is necessary in determining the optimum combination of spatial pattern and site specific land use measures for use in an environmental management plan. A strategy that requires a particular section of a region to slow its rate or re-

directs its urban growth because of anticipated environmental problems must be technically supportable if it is to gain political acceptance. Another equally effective strategy for reducing pollution, which may get the support of a larger number of elected officials, could be one that permits increased growth but requires high levels of abatement or mitigation measures included in new development. Because of the importance of these different strategies, they will be discussed in greater detail.

SPATIAL PATTERN STRATEGIES

Empirically based consideration of the relationships between urban form and environmental quality is still in its germinal stage. There has been relatively little work on the subject and results are sketchy, difficult to verify and often conflicting. Until recently research on urban form and its relationship to environmental quality has focused on air quality questions. This orientation is understandable in that automobile travel patterns and the distribution of air pollutant sources, two of the major air quality components, are clearly linked to urban form.

Some explorations of the air quality/urban form question are theoretical in nature. "Air Pollution and Urban Regions", a research note by C. Peter Rydell and Benjamin H. Stevens which appeared in the Journal of the American Institute of Planners in January 1968, provides a good example of the initial work in this area. The article presents a theoretical study using a simple urban structure, direct links between travel and pollutant generation and an uncomplicated notion of pollution dispersion. Using a series of equations, a hypothetical spatial form is found that makes for an optimal mix of trip lengths and distributions, thereby minimizing the city's exposure to pollutants.

A more recent example of this kind of hypothetical analysis is provided in the earlier cited Guide for Reducing Air Pollution Through Urban Planning. A hypothetical metropolitan area of 625 square miles and 2.5 million people was simulated. Varying assumptions were made concerning overall urban form and highway and transit systems, creating eight simplified alternatives. Using a computer, vehicles miles travelled (VMT) were projected for each alternative and used to predict air pollutant concentrations. A satellite cities configuration was found to have the shortest trip lengths, and decentralized configuration with strong radial corridors was found to allow the heaviest transit use. The conclusion reached was that the radial corridor configuration produces the best air quality conditions.

Several air quality/urban form studies were carried out in the late 1960's and early 1970's that were more practical in their focus. Typically, modeling techniques were applied to determine the air quality conditions that could be expected to accompany alternative development patterns hypothesized for a specific metropolitan region. The conclusions from these earlier studies are heavily oriented to generation of pollutants and give only minimal attention to the dispersion of pollutants by differing meteorologic conditions. In addition, many of the findings were area specific and they cannot be readily transferable to other metropolitan areas. The benefit of these studies lies more in

understanding the analytical approaches for studying the impact of spatial pattern on air quality. One of the first studies of this type was Summary Report: Air Pollution Study of the Capitol Region an analysis by Yocum, Chisholm, and Collins (1967) of regional development alternatives proposed for the Hartford metropolitan area. A study by Kurtzweg and Weig (Determining Air Pollution Emissions from Transportation Systems) sought an optimal development configuration for the Seattle area that would limit pollutant generation. The Northern Illinois Planning Commission (NIPC) (Managing the Air Resource in Northern Illinois, Technical Report No. 6, 1967), modelled three alternatives: a finger (corridor) plan, a multi-towns plan and a satellite cities plan to test for the levels of oxides of nitrogen and particulates that they would create. The NIPC study found that the finger plan and satellite plan had the lowest concentrations of particulates, and that the finger plan had the lowest NO_x levels.

Generally similar analytic techniques were applied at a somewhat smaller geographic or non-metropolitan scale in the following studies: A Transportation Study for Montgomery and Prince Georges Counties, Maryland (Voorhees and Assoc., 1974) and The Hackensack Meadowlands Air Pollution Study - Task 4 Report: Air Quality Impact of Land Use Planning (Willis, Mahoney, and Goodrich, 1973). These studies highlight the problems of analyzing small areas whose air quality problems are largely created by pollution from other parts of the metropolitan area.

A revealing county level analysis, completed not too long ago for Middlesex County, New Jersey, is entitled Air Quality Management Plan and Program Recommendations Middlesex County, New Jersey (TRW, Inc., 1974). Two alternative land use plans were projected for the year 2000. One emphasized controlling growth to concentrate it around the county's present urban centers; the other was a "continuation of trends" scenario that anticipated dispersed ("sprawl") development. The air quality modeling indicated that the concentrations of SO_2, particulates, and CO would increase for both scenarios, even though the effects of pollution control technology were taken into account. Of greatest interest was that in the controlled growth alternative, high pollutant concentrations were created in and around the intensified urban centers. Periods of highest concentrations were considerably lower, but they spread over a wider area in the "sprawl" alternative.

Up until now, no analogous studies have been carried out to relate alternative regional development forms to water quality. The lack of generalized water quality/urban form analysis may be due to the very nature of water quality relationships themselves. Water quality is very dependent on the characteristics of the local hydrologic system and its ability to assimilate pollutants. These characteristics are highly variable from one metropolitan area to another, depending on such factors as configuration of the drainage system, flow volumes and patterns and climatic regimes. Water quality is also sensitive to the specific type of the wastewater collection and treatment systems used, which does not relate directly to metropolitan structure.

Perhaps the most comprehensive assessment of the relationship between urban structure and overall environmental quality that has been made to date was carried out by Brian Berry and colleagues at the University of Chicago entitled Land Use, Urban Form, and Environmental Quality (1974). It considers the linkages between the spatial form of metropolitan development and a variety of environmental quality factors, including both air and water pollution. Unlike the preceding air quality/urban form analyses, it focuses on existing rather than hypothetical urban systems. Data from 76 American metropolitan areas was assembled and statistically analyzed to produce some observations about the nature of urban structure/environmental quality relationships. Because the study is broad in scope, and has an empirical basis, its findings are of unusual interest.

Information on city characteristics (population factors, density and employment) and urban form (number of degrees of arc and number of radial and circumferential highways) were gathered for each of the 76 urban regions. Additionally, for each urban area, a standardized set of environmental quality indicators was prepared. Using the environmental quality data as a base, factor analysis was applied to generate a typology of urban regions with similar environmental quality characteristics. Once the typology was created, an attempt was made to determine 1) the differences in the environmental characteristics of each group, 2) the differences in urban characteristics and regional form from group to group and 3) how the pollution differences and urban characteristics vary. These objectives were achieved in a limited way by comparing the mean city characteristics, urban form variables and environmental variables for each of the groups. On the basis of these initial comparisons, it was concluded that the largest metropolitan areas with high residential densities and high levels of manufacturing employment have the highest levels of air and water pollution and generate the greatest volume of solid wastes.

A second level of analysis was carried out, holding the major variables of size, density, and manufacturing constant to determine what effects urban form and land use have on increasing or decreasing environmental pollution. One of the second stage analyses involved creating a series of regression equations relating environmental quality indicators to the independent variable of SMSA population, density ratio, median family income and percentage of labor force employed in manufacturing. Equations were developed for 14 dependent variables, including aggregate air quality, concentrations of sulfur dioxide, nitrogen dioxide, and total suspended particulates. Water quality indices were also developed related to aggregate water quality, drinking use, recreation use, and industrial use.

On the basis of the relationships detected through statistical analysis, the study concludes that when city size and manufacturing concentrations are taken into account:

"1. The core oriented urban region with a radial transportation network and a steep density gradient

a. displays greater intensity of land use, a lower percentage of land developed and used for residential and commerical purposes and more open space, and

b. as a consequence of this land use mix and pattern, has a superior air and water quality to:

2. The dispersed urban region with a less focused transport network and lower, more uniform population densities

   a. displays urban sprawl with a higher percentage of residential and commercial land use and less open space than in the core oriented case, and

   b. as a consequence of this land use mix, has inferior air and water quality." (p. 413)

SITE SPECIFIC MANAGEMENT TECHNIQUES

In contrast to the research on spatial pattern, a much more extensive body of literature has been written on site specific management techniques for improving air and water quality. Rather than providing an exhaustive survey of the available material, an attempt has been made to cite the works which are the most value in meeting the informational needs of practicing planners.

Site Specific Management Techniques for Water Quality

There is a fairly large body of recent literature dealing with the relationship between water pollution and land use on the subregional or site specific level. Most of this literature is authored by private consulting firms and university research groups, largely under the sponsorship of the U. S. Environmental Protection Agency. This literature may be classified into two basic groups - problem description-oriented and solution-oriented. The problem description-oriented works focus the bulk of their research on describing or quantifying the nature of specific problems giving only minimal attention to solutions. The solution-oriented works, on the other hand, describe the problems rather briefly and devote most of the work to exploring possible solutions.

An elementary primer for planners is Urban Planning Aspects of Water Pollution Control (Grava, 1969) which covers the nature of water pollution problems, treatment systems, administrative and financial considerations, and relationships to local planning. Water Pollution Aspects of Urban Runoff (American Public Works Association, 1969) is a basic work analyzing the pollution effects of urban runoff based on field data and theoretical calculations. Factors considered include street refuse, catch basins, air pollution fallout and sewer solids deposition. A more

recent study conducted by the Regional Science Research Institute titled Stream Quality Preservation Through Planned Urban Development (Coughlin and Hammer, 1973) establishes relationships between amount, density, type and location of urban development and stream water quality and channel enlargement.

The body of literature that deals with solving land use related water pollution problems ranges from works dealing with regulations and ordinances intended for planners and government officials to site design specifications intended for engineers and designers. On the former topic, the most comprehensive document is the report prepared by ASPO for the U. S. Environmental Protection Agency entitled Performance Controls for Sensitive Lands: A Practical Guide for Local Administrators (Thurow, et al., 1975). It identifies sensitive geographic areas and discusses current regulatory practices and recommends programs for regulating these areas. Also provided are examples of local ordinances, information on where to go for technical assistance from government agencies, summaries of pertinent state and federal legislation and legal decisions relating to sensitive lands and an extensive annotated bibliography. The Water Resources Center at the University of Delaware has prepared two excellent site-specific studies dealing with land use planning and on-site measures to protect water resources. The studies are Water Resources as a Basis for Comprehensive Planning and Development in the Christina River Basin (Tourbier, 1973) and Water Resources Protection Measures in Land Development - A Handbook (Tourbier and Westmacott, 1974). The earlier of these works defines land use controls which can be used to direct urban land uses onto areas where they are expected to do the least damage and outlines environmental protection measures to incorporate into development as it proceeds. This study is based on the assumption that the cost of solving water related problems on-site is far less than trying to solve the resulting off-site problems, such as flooding and siltation. The latter work is essentially a detailed handbook describing measures to lessen the effects of urban development on water quality and quantity. Measures to control increases in runoff or decreases in infiltration, soil erosion, sedimentation, stream bank erosion, flood damage, runoff pollution and sewage effluent pollution are discussed. Included in such descriptions are site characteristics, advantages and disadvantages, references, design specifications, case study information, cost guidelines, maintenance requirements, implementation considerations, and legal implications of each of the recommended measures.

Three reports intended primarily for engineers and designers are Urban Stormwater Management and Technology - An Assessment (Lager and Smith, 1974), Approaches to Stormwater Management (Becker, et al., 1973), and Management of Urban Stormwater Runoff (McPherson, et al., 1974). The Lager study is a comprehensive description and evaluation of engineering projects and methods for the collection, retention and treatment of stormwater with an emphasis on major off-site facilities. The Becker report describes fifteen basic techniques for stormwater management, including surface and sub-surface detention and infiltration systems. The latter volume contains eight lectures delivered at a training

course on "Management of Urban Storm Water, Quantity and Quality" sponsored by the Hydrologic Engineering Center of the U. S. Army Corps of Engineers. This report covers a variety of topics including both quantification of the problem as well as discussion of alternative solutions.

The majority of the works reviewed deal with the problem of runoff and non-point source pollution. Methods for Identifying and Evaluating the Nature and Extent of Non-Point Sources of Pollutants (U. S. Environmental Protection Agency, 1973) provides detailed descriptions of four non-point sources of pollution - agriculture, silviculture, mining and construction. Water Quality Management Planning for Urban Runoff (U. S. Environmental Protection Agency, 1974) is primarily a manual of procedures for quantification of urban nonpoint source pollution problems in local planning areas.

Works emphasizing specific solutions to runoff problems include Practices in Detention of Urban Stormwater Runoff (Poertner, 1974) and Processes, Procedures and Methods to Control Pollution from All Construction Activity (U. S. Environmental Protection Agency, 1973). The former work covers all aspects of on site detention facilities, including planning, designing, financing, regulating, operating and maintaining such facilities. It provides detailed information of specific site-scale, engineering measures and offers a good background for developing design-review criteria related to runoff. In addition, references are made to ordinances in effect in various communities.

Two good studies dealing with the problem of runoff from streets are Water Pollution Aspects of Street Surface Contaminants (Sartor and Boyd, 1972) and Contributions of Urban Roadway Usage to Water Pollution (Shaheen, 1975). The Sartor study provides a description of street pollutants and cleaning practices of various cities and quantifies the efficiency of various street cleaning techniques. The Shaheen report details the origin and composition of roadway dust and dirt. Both works include recommendations regarding street cleaning practices, curb and gutter design, roadway site selection, porous pavement and other techniques to reduce the problem.

Site Specific Management Techniques for Air Quality

Specific ideas for use of land use control measures in air quality planning began appearing in reports in the early 1970's. A brief introduction to this topic is found in "Urban Planning and Air Pollution Control: A Review of Selected Recent Research" (Kurtzweg, JAIP, 1973). The article includes a discussion of land use and transportation planning measures for improving air quality along with a review of applicable federal legislation and policies. It also presents a number of projects initiated by the National Air Pollution Control Administration and continued by the Environmental Protection Agency. The projects funded were to demonstrate the value of incorporating air quality considerations into urban planning. More specifically, the projects dealt with land use patterns and density, site specific structures and operations and planning and design of transportation systems.

A large amount of literature pertaining to the various strategies, measures and methods for incorporating air quality into the planning process was initiated by the Environmental Protection Agency in an ongoing series titled Guidelines for Air Quality Maintenance Planning and Analysis. The purpose of this series was to assist local and state agencies in the development of Air Quality Maintenance Plans.

The third report in this series, Guidelines for Air Quality Maintenance Planning and Analysis - Volume 3: Control Strategies (Research Triangle Institute, 1974) is especially valuable to local planners in the early stages of identifying measures applicable to their areas. It defines 18 measures for maintenance of air quality standards. Nine of these measures relate to land use and planning including emphasis on indirect emission sources. Some of the measures are density zoning, environmental impact statements and emission charges. The remaining nine measures presented are concerned with existing direct emission sources.

Another report aimed at the planner with minimal technical background in air quality analysis is A Guide for Considering Air Quality in Urban Planning (Environmental Research and Technology, 1974). It outlines a five step procedure for integrating air quality considerations into the planning framework. An excellent tool for planners is the Air Quality-Land Use Planning Handbook for California - Part I: Planning for Air Quality (California Air Resources Board, 1975). It gives explanations of how and where air quality objectives can be achieved and maintained at the local and regional level. The handbook provides background information, specific planning mechanisms and evaluation processes for air pollution.

There are several area specific studies of value to local planners. The Air Quality Plan of San Bernardino County (San Bernardino County Environmental Improvement Agency, 1975) is a example of the actions which can be taken by local governments to reduce the generation of air pollution. Included in this discussion of transportation and land use strategies are various land use incentive programs aimed at reducing air pollution generated by cars. The Plan also presented an "Air Quality Indexing System" based on critical receptors (pollution sensitive variables) and emitters (pollution causing variables).

Development of A Trial Air Quality Maintenance Plan Using The Baltimore Air Quality Control Region (Engineering Science, 1974) contains a useful table of control measures with the corresponding implementation policies for suspended particulates and hydrocarbons. Factors evaluated in the table are economic, admistrative, political, legal and environmental effectiveness. The San Diego Clean Air Project: Summary Report (Goeller, 1973) reviews the procedures and findings of a research study that evaluated the costs and effects of strategies designed to improve and maintain air quality in the metropolitan area. In general, the results tend to support the implementation of source controls rather than land use and transportation controls as a best approach to the region's air quality problems.

In the area of air quality planning through transportation controls, Transportation Controls to Reduce Automobile Use and Improve Air Quality in Cities; the Need, the Options, and Effects on Urban Activity (Horowitz, 1974) is a summary of the rationale for transportation controls, the primary methods for reducing automobile use, the revelant control mechanisms and the consequences of reducing automobile use. Evaluating Transportation Controls to Reduce Motor Vehicle Emissions in Major Metropolitan Areas (Institute of Public Administration, 1972) and Guidelines to Reduce Energy Consumptions through Transportation Actions (Voorhees, 1974) are good examples of the other numerous reports detailing transportation control strategies.

SUMMARY OF SITE SPECIFIC MANAGEMENT TECHNIQUES

In the accompanying Table III-1, the locational and site design measures most frequently proposed in the literature are summarized, and the implementation devices available to effectuate them are noted. The measures cited are described in detail in Guide to Implementation Techniques for Air and Water Quality Management Plans a report prepared for ABAG in 1976 by the Sedway/Cooke consulting firm. Besides describing the intent and use of each measure, the report also evaluates their potential application in addressing air or water quality concerns. Basic principles underlying air quality related measures are to:

1. Disperse major sources of pollutants so that the assimilative capacity of the air is not overloaded in any one area.

2. Locate housing, schools, hospitals and other pollution sensitive uses away from pollution sources and concentrations.

3. Buffer sources and receptors from each other.

4. Reduce the generation of pollutants by altering travel and consumption patterns.

The principles underlying the measures suggested to protect water quality are to:

1. Locate urban and industrial uses in areas where the waterways are capable of assimilating the effluents produced.

2. Regulate the location and operation of agricultural resource extraction, and other rural activities so that their discharges can be appropriately assimilated.

3. Limit the generation of wastewater and surface runoff and regulate its entry into natural waterways.

4. Reduce the waste loads carried by runoff by controlling erosion, the use of fertilizers and pesticides and by promoting improved urban housekeeping practices.

TABLE III-1 LAND USE MEASURES DESIGNED TO IMPROVE AND MAINTAIN WATER QUALITY

MEASURES	IMPLEMENTATION METHODS
Control of Location and Concentration of Sources	
Point Sources	
° location of sewage treatment plants where effluents can be best assimilated by hydrologic and land systems	"201" plans administrative/funding policies environmental assessment review
° channeling of development into areas that can be readily served by appropriately located treatment facilities	zoning capital improvements development moratoria
° holding development in sewered areas to the design capacities of the STP's and/or the assimilative capacities of the receptor of their discharges	zoning district regulations capital improvements
° location of power plants, industries, and processing plants where their effluents can be appropriately assimilated by natural systems	permits (based on an emissions-density concept) zoning
Nonpoint Sources	
° permit unsewered development only in areas where soil and other environmental conditions permit successful long-term operation of septic or other acceptable on-site treatment systems	zoning special permits
° set stringent regulations on the design, construction in and maintenance of septic systems	public health regulations
° ensure that densities in unsewered areas are kept low enough to prevent septic systems from overtaxing the assimilative capacity of the groundwater	zoning
° restrict agricultural forestry and mining activities to areas where discharges can be appropriately assimilated	zoning permit-system
° stage construction and development activities so that erosion levels do not exceed the assimilative capacity of the watershed	capital improvements permit system zoning (performance standards)

TABLE III-1 LAND USE MEASURES DESIGNED TO IMPROVE AND MAINTAIN WATER QUALITY

Site Design and Resource Management Controls

Limitation on Wastewater Generation	
° Recycling - this isn't a land-use measure per se, but it may well have land-use ramifications - as in reserving lands near treatment plants for users of recycled water (agriculture, golf courses, industries)	zoning capital improvements agricultural preserves
° separation of existing storm and sanitary sewer collection	redevelopment capital improvements
° reduction of wet-weather flows by increasing infiltration into interceptors	zoning (physical form, siting requirements) subdivision regulations design review
Reduction and Control of Runoff	
° limitations on the amount of impervious surface	zoning (physical form, siting requirements) subdivision regulations design review
° use of porous paving materials	zoning (performance standards) subdivision regulations design review capital improvements
° creation of retention ponds	zoning (performance standards) subdivision regulations design review capital improvements
° preservation or creation of recharge areas	zoning (physical form, siting requirements) agricultural preserves flood plain zoning subdivision regulations design review
° modification of agriculture and forestry practices (contour plowing, field arrangements, selective cutting, cutting in mosaic patterns, etc.)	soil conservation district regulations
Reduction and Control of Erosion	
(many of the runoff reduction measures also limit erosin by reducing the volume and intensity of surface flow)	
° protection of natural ground cover	zoning (performance standards) hillside and soil

TABLE III-1 LAND USE MEASURES DESIGNED TO IMPROVE AND MAINTAIN WATER QUALITY

	conservation regulations grading regulations subdivision regulations design review soil conservation district regulations
° replanting or special treatment of disturbed areas	zoning (performance standards) hillside and soil conservation regulations grading regulations subdivision regulations design review soil conservation district regulations
° protection of natural drainage ways	zoning flood plain zones subdivision regulations design review capital improvements (purchase of stream banks)
° limitation of development on steep slopes and highly erodible soils	zoning (performance standards) hillside and soil conservation regulations design review strategic capital improvements

TABLE III-1 LAND USE MEASURES DESIGNED TO IMPROVE AND MAINTAIN AIR QUALITY

MEASURES	IMPLEMENTATION METHODS
Control of Location and Concentration of Sources and Receptors	
Point Sources	
° location of industries, incinerators, and power plants in areas where the air system is capable of adequately assimilating their emissions	emission density zoning special permit techniques environmental assessment review
° location of indirect sources (e.g. shopping centers, stadiums), in areas where the air system is capable of adequately assimilating the emissions associated with them.	special permit techniques emission density zoning environmental assessment review
Line Sources	
° location of major thoroughfares where emissions can be best assimilated	capital improvements
Area Sources	
° location of activities and land uses in areas that have sufficient assimilative capacity to maintain acceptable air quality	zoning capital improvements environmental assessment review
Critical Receptors	
° location of sensitive receptors (schools, hospitals, rec. facilities) in areas that are likely to retain superior air quality	zoning environmental assessment review
° restrict housing development in areas that have, or are likely to experience unacceptable air quality levels	zoning capital improvements (e.g. not funding sewage treatment plant development moratoria
Site Design and Resource Management Measures	
Buffering of Sources	
° segregation of industries, indirect and line sources from living areas and other sensitive receptors	zoning district regulations special zones subdivision regulations capital improvements (e.g. buying open lands in strategic locations) design review

TABLE III-1 LAND USE MEASURES DESIGNED TO IMPROVE AND MAINTAIN AIR QUALITY

◦ creation of artificial buffers around sources (such as by creating heavily planted buffer strips)	zoning subdivision regulations capital improvements (e.g. buying open lands in strategic locations) design review
Buffering of Receptors	
◦ requirement for housing to be set well back from freeways, major arterials, and other significant sources of air pollutants	zoning district regulations subdivision regulations design review environmental assessment review
◦ requirement for planted open spaces where subdivisions or housing projects abutt major roadways or other major pollutant sources	zoning regulations subdivision regulations environmental assessment review
◦ placement of active recreation areas in the centers of parks and school yards, away from the surrounding thoroughfares	design review environmental impact assessment
◦ where possible, creating bicycle lanes that do not run along side major streets	subdivision regulations capital improvement program design review
Reduction of Energy Use	
◦ requirement for building designs and orientations to reduce heating and cooling energy demands	building codes subdivision regulations zoning and design review
◦ neighborhood designs to reduce automobile use at the local level (some of the notions involved here include providing a high enough density and mix of uses to allow most everyday facilities to be within convenient walking distance from home)	subdivision regulations design review zoning
<u>Transportation Strategies</u>	
Limitations on Automobile Use	
◦ parking restrictions	parking ordinance
◦ reduction in the number of parking spaces required for most land uses by zoning regs.	zoning changes

TABLE III-1 LAND USE MEASURES DESIGNED TO IMPROVE AND MAINTAIN AIR QUALITY

◦ restriction of construction of parking garages in selected areas	zoning development moratoria
◦ creation of car-free zones, pedestrian malls	zoning redevelopment
Emphasis on Public Transit	
◦ construction and upgrading of transit facilities	capital improvements
◦ improving interface between transit and other transportation modes	zoning subdivision regulations redevelopment
◦ fostering densities and land-use mixes that can support public transit	zoning district regulations redevelopment
Reduction of the Need to Travel (reduced vehicle trip frequency and lengths)	
◦ creation of multi-use centers	zoning redevelopment capital improvements
◦ creation of residential areas with high amenity levels	zoning (planned unit developments) subdivision regulations captial improvements design review

SEWAGE SYSTEMS AS A DETERMINANT OF REGIONAL GROWTH

The use of public utilities as a means of directing urban growth has long been advocated in planning literature. More recent attention to the subject has been initiated by EPA through efforts encouraging the development of sewage collection and treatment facilities that will result in urban growth patterns that do not contribute to a continued violation of air quality objectives. However, there are a large number of considerations other than public utilities that influence the location and timing of urban development. A considerable amount of research has been conducted attempting to identify the factors involved in development and the relative roles that they play.

One of the classic works in this area is Urban Growth Dynamics in a Regional Cluster of Cities (Chapin and Weiss, 1962), a study of urban development processes in the Carolina piedmont. The study concludes that the development of vacant land is encouraged or intensified by location of major transportation routes, employment centers and the availability of community services, and that development is discouraged by poor drainage conditions or proximity to non-white and/or blighted areas.

The City Expands (Milgram, 1967) focuses on the urban expansion into Philadelphia's northeast district. Its analysis determined that the timing of new development was largely related to access to the central business district. Whether the lack of sewers delayed development in areas where builders were prepared to build, or whether the sewer lines directed new development into areas preferred by the city could not be clearly determined. Although there has been some success in identifying the factors affecting development, understanding of their relative importance in determining the location, timing, and form of what happens has proven to be much more difficult. In 1972, a HUD advisory committee concluded that: "...despite growing public concern, we know relatively little about the import or impact of processes leading either to the development and use of raw land, or to the changes in density and uses of developed land." (Urban Growth and Land Development; the Land Conversion Process (Land Use Subcommittee of the Advisory Committee to the Department of Housing and Urban Development, 1972). The imperfect knowledge of the development process has made research into the sewer/growth question highly speculative.

One of the most comprehensive and thorough reviews of the sewer extension/urban development question is contained in Secondary Impacts of Transportation and Wastewater Investments: Review and Bibliography (Bascom et al., 1975). Besides providing an evaluation of the literature, the report provides a cogent statement of the relationships between the availability of sewer service and various kinds of development. The report observes that the presence of sewer service has a direct effect on the location and character of housing, and a more indirect effect on the location of industry and commerce. It points out that the location of industry depends the most on access to markets and labor and that the relative influence of sewer service is fairly small. In fact, the report states that because communities are generally anxious to attract industry, they are often willing to make a special effort to provide the required service

on demand, and often at a nominal cost. The situation cited for commercial land users is somewhat parallel, except that these uses can also quite frequently be seen as secondary impacts of sewer service provision - with the housing stimulated by the new sewers attracting commerical activities to serve it.

The Bascom report also observes that although the lack of sewer services does not always prevent the development of single family housing (homes on large lots served by septic tanks are often an alternative), the construction of new sewer lines does open up new land for development. Newly sewered land tends to develop faster than previously served areas because developers rush to buy the land before its value shifts up the levels normally associated with sewered land. The report goes on to point out that:

> "Generally, significant increases in single family housing construction can be expected to follow new sewer investments in areas where there is little vacant, sewered land, where vacant land prices are low relative to the regional average, and where large tracts of contiguous underdeveloped land exists." (p. 21)

Increases in high density housing are seen in situations where the newly sewered land also has high accessibility. The conclusion is that extending sewer service to a new area creates increased land values and encourages speculation. Dispersed, sprawl-like development is seen as the consequence, a condition which is interpreted as leading to fiscal problems and decreased water quality due to increased runoff loads.

Other case studies dealing with the sewer/urban development question include Interceptor Sewers and Suburban Sprawl: The Impacts of Construction Grants on Residential Land Use (Urban Systems Research and Engineering, Inc., 1974) and Water Resources Management for Metropolitan Washington: Analysis of the Joint Interactions of Water, Sewage Service, Public Policy and Land Development Patterns in an Expanding Metropolitan Area (Promise and Leiserson, 1973).

Increased attention is now being given to consciously applying sewer service extension policies as a means to achieve desired urban development patterns. A good explanation for the movement in this direction is provided by a discussion in the Fifth Annual Report of the Council on Environmental Quality (CEQ, 1974). The CEQ notes that since virtually all interstate freeways have been completed throughout an entire metropolitan area, sewers and sewage treatment plants have become prime determinants of urban growth. It points out that water pollution controls have restricted the opportunities to use septic tanks and made it more difficult to tie into overburdened sewer systems. Federal grants of 75% of the costs have encouraged the upgrading and expansion of community sewage treatment facilities, making it cheapest for developers to build where they can take advantage of these systems. The report also notes that many of the federally funded treatment plants are regional facilities, requiring interceptor sewers to run through undeveloped land between communities, possibly encouraging sprawl along their right-of-ways. Additionally, the plants and interceptors have often been oversized, stimulating increased development. These factors have already been recognized as posing problems for sound environmental

development. In California, for example, the State Water Resources Control Board limits the federal and state funding of local sewage treatment plants in critical air basins to the capacity justified by the State's low range population projections. Planning and Human Values, an Inquiry into the Phenomenon of Urban Growth and the Possibility of Its Control Through Water and Land Related Actions (Salama, 1974), a recent EPA-sponsored report, suggests that infrastructure investment can be a powerful tool for influencing urban development, especially in inner-city areas and in metropolitan areas in the early stages of growth. The conclusion is that strategic infrastructure investments can have the most effects where:

> "...growth potential and demand for space are strong, where the direction of that growth can be influenced by the creation of marginal advantages,...and where the scale of intervention is large relative to other development resources." (p. 65)

A growth control strategy that is often related to the strategic provision of sewer service is the development moratorium. The Fifth Annual Report of the CEQ noted that in 1973-74 period, over 200 local development moratoria were put into effect. The Sewer Moratorium as a Technique of Growth Control and Environmental Protection (Rivkin/Carson, Inc., 1973) identified six different forms that development moratoria can take:

"1. A freeze on new sewer authorizations (i.e., the extension of trunklines into currently unsewered areas).

2. A freeze on new sewer connections (i.e., the actual hookup of a building to an existing trunk or feeder line).

3. A freeze on the issuance of new building permits, or a freeze on a class of building permits such as multi-family.

4. A freeze on the approval of subdivision requests.

5. A freeze on rezonings or zonings to higher than presently developed densities.

6. A slowing down or a quota allocation for any or all of the above within an affected area." (p. 2)

The Rivkin/Carson report found that so far, development moratoria have had mixed results. On the positive side, moratoria:

1. Have in some cases possibly relieved the physical problem they were intended to address.

2. Have provided an impetus to infilling of vacant land where sewer connections are available.

3. When applied in suburban areas could encourage reconcentration in the central cities where utilities are already available.

On the negative side, moratoria have:

1. Stimulated short-term spurts of construction followed by sharp drops in activity if facilities have not been provided promptly.

2. Caused hardships and inequities for small builders.

3. Discriminated against apartments and other efficient higher density housing in some areas.

4. Created roadblocks to the provision of low and moderate income housing by contributing to escalation of land costs and discriminating against higher densities.

5. Encouraged urban sprawl in areas beyond the jurisdiction imposing the moratorium by encouraging use of septic tanks and package treatment facilities which may not provide adequate treatment.

6. Provided a stimulus to complicated bureaucratic processes and capital works delays.

It is clear that all the facts are yet available on the growth moratorium question. Further monitoring and careful evaluation of actual experience will be necessary before complete assessment of their utility and the circumstances under which they are appropriate can be made. Special attention will have to paid not only to the direct effects of moratoria on growth, but their indirect effects on air and water quality as well.

RESIDUALS MANAGEMENT AS AN APPROACH FOR INTERRELATING LAND USE/AIR QUALITY WATER QUALITY

In considering the notion of applying land use strategies to achieve air and water quality objectives, one of the questions that arises is the extent to which measures intended to improve air quality will conflict with or reinforce those intended to improve water quality. This issue has received increasing consideration by EPA. The general question of the interrelationships of pollution control measures is given attention in the residuals management literature. (Residuals management is used in this context to be the very broad concern with all forms of wastes as distinct from perhaps its more familiar reference to sludge from wastewater treatment process.) Residuals management is an analytic approach to air pollution, water pollution and solid waste issues that treat the questions in a comprehensive, systemic way. The relationships between the various types of pollutants in their receiving media are considered, and trade-offs are made in devising the least-cost strategies for pollution abatement. The residuals management approach is best described and its use demonstrated in Environmental Quality Analysis (Kneese and Bower, 1972) and Residuals - Environmental Quality Management: Applying the Concept (Bower and Basta, 1973).

A report for EPA entitled Development of Residuals Management Strategies (Howe and White, 1975) provides a general descriptive model for identifying and evaluating residuals management strategies. The report also dis-

cusses some administrative and legal considerations in preparing the strategies. Unfortunately, to date none of the studies on residuals management have focused in detail on the various land use based approaches that have been suggested for air and water quality improvement and therefore provided little direct assistance to the formulation of the Sonoma Study.

SUMMARY

The present theories on the interrelationships of air and water quality and land use provided strong direction to the Sonoma Study. Based on the findings from the literature survey, the study has concentrated on three subject areas where earlier research was either lacking or limited.

The first subject area for study is the relationship of land use controls designed to meet air quality objectives to those designed to meet water quality objectives. Of particular interest is whether the land use control strategies for either medium is supportive or conflicting.

The second consideration of the Sonoma Study is the impact of spatial pattern on air and water quality. Most of the earlier studies on spatial patterns concentrated solely on air quality. The Sonoma Study is designed to consider both media and to determine if any of the elements of spatial pattern -- population size, location, density or land use type -- is the dominant characteristic and how these elements are related to each other.

Finally, the study focuses on the effectiveness of spatial pattern or site specific management devices for achieving and maintaining environmental objectives. The intent of this analysis is to provide direction to those public agencies preparing environmental management plans on what would be an optimal planning strategy in using both types of controls.

CHAPTER IV - GOVERNMENTAL STRUCTURE OF AIR AND WATER POLLUTION CONTROL IN CALIFORNIA

Governmental structure for air and water quality management has come under considerable scrutiny. recently, with attention being directed to how environmental protection programs can be made more effective. A particularly perplexing issue is how to integrate the policies and implementation programs of various state, regional and local agencies into a more cohesive approach to environmental management that also considers social and economic objectives. This chapter describes those public agencies at the state, regional, local and special district levels concerned either directly or indirectly with the attainment and maintenance of acceptable levels of air and water quality in the study area. This description includes: (1) the specific nature of the jurisdiction, including its purpose, means of policy setting, enforcement powers, intergovernmental relationships, nature of existing policies and relationship, of plan or plan enforcement to Sonoma County, and (2) an evaluation of the air and water pollution control structure in California.

HISTORIC PERSPECTIVE OF ENVIRONMENTAL CONTROL

This chapter presents a picture of air and water pollution control in California that is both extensive in terms of actors but disjointed in terms of its operation. This disjointed approach to environmental management results in a confusion as to whether the present or potential effectiveness of either the controls of an individual agency or the collective sum of controls by all agencies are adequate. This confusion raises the further questions: (1) will such controls meet the legal mandates of state and federal legislation, (2) are they satisfactory to a continuously changing public demand and (3) can state, regional, or local policy makers act on recommended controls with any confidence in their effectiveness?

Much of this confusion is the result of the past six years of rapid promulgation of environmental regulations at all levels of government. It is therefore necessary to place this period into a historical perspective to better understand the reasons for such confusion.

The factual information on environmental deterioration has been well documented for the past twenty to thirty years and had resulted in an increased level of political awareness on the subject. California was perhaps more sensitive to the issue than other states in that it created (1) a state and regional water pollution control system in 1949 and (2) enabling legislation in 1947 for county level Air Pollution Control Districts (APCD) to control stationary source emissions.

The national awareness of the severity of air and water pollution problems came in the late 1960s and appears to have come in part out of declining attention to one set of national problems - civil rights, poverty and the Vietnam War - and in part from a realization that the

"ecology" issue had considerable merit. Environmental improvement provided a new cause that could be attacked with the same political fervor of the civil rights or anti-war movement, but it also had a constituency that had not been embroiled in earlier political confrontation. The constituency included people from such groups as fishing, naturalist, hiking or garden clubs who had not previously been involved in the then current political debate. The fight against pollution, therefore, provided national level policy makers with a means of re-channeling the energies of discontent to a subject matter that was new and genuine and that was perceived as being less volatile. It brought to those long concerned with the environment political support for the development of quick solutions to large and complex problems.

Another historical event that would seem to have shaped the political atmosphere for environmental management was the landing on the moon. This event evoked a national pride that American engineering and technology could solve overwhelmingly complex problems under extremely short time periods. The impact of the moon landing on the fight against pollution was to create a strong confidence that engineering and large project planning could quickly clean up the nation's air or water. Such normally vague terms as "best available technology," which has been used recently in the federal statutory scheme to describe the desired 1983 sewage treatment level, attest to the political leaders' faith that engineering ingenuity can come up with new and yet undefined treatment methods. Implicit in such a descriptive phrase is the belief that technological advances can be made if we simply place the pressures on our economic and governmental system to find them.

The dilemma is that much of the legally required solution to air and water pollution cannot be provided solely by technological solutions. They require changes in governmental organization, in land use patterns or activities and in the way people have become accustomed to living. The potential of short-term environmental change under these approaches is less than through engineering inventions. Yet, the basic federal or state air and water pollution laws have been very specific in terms of their desired intent, including exact timetables for compliance and penalties against those polluters that cannot comply with the timetables.

The planning effort for air and water quality took on a whole new direction not previously seen in other federally initiated planning requirements. Its equivalency would have been if the 1949 Housing Act, which stated the national intent of a "decent home and a suitable living environment for every American family," had included the additional proviso that the intent was to be satisfied by 1960 or cities would find their urban renewal money restricted, and federal and state government would become directly involved in correcting local housing problems.

It was with this background that states, counties, cities and special districts have hastily expanded their environmental improvement efforts. The result is that the sense of urgency appears to have required the compromising of a more integrated governmental approach involving all concerned agencies in providing needed improvements.

STATE AGENCIES INVOLVED IN AIR AND WATER QUALITY

There are six state agencies involved directly with air and water quality in the Sonoma study area and a number of other state agencies, such as the State Board of Forestry and the Department of Agriculture, that are also involved but whose activities are less direct and will not be discussed in this study. There is also a major state agency concerned with both air and water, the Coastal Zone Conservation Commission, whose jurisdiction was not in the study area.

The different state agencies are not identical in terms of their organizational structure or nature of policy setting. Some of the state agencies, like the State Water Resources Control Board or the Air Resources Board have been organized to respond in part to federal environmental requirements, while others have been established and organized to direct state initiated environmental programs. Some state agencies have substate planning and enforcement agencies such as the Regional Water Quality Control Boards. Unfortunately, for the reader wishing to readily understand the California network, the state agencies do not lend themselves to a single classification system. Therefore, they will be discussed in a sequential fashion based roughly on their importance to air or water quality with those agencies with complementary substate or regional divisions presented together.

Air Resources Board

In 1967, the California Legislature enacted the Mulford-Carrell Act, establishing the Air Resources Board (ARB) to deal with the State's air pollution problems. The ARB has authority over motor vehicle emissions, including responsibility for motor vehicle emission standards and certification of devices for the extensive California used car retrofit program. Another ARB function is to review, evaluate and change (if necessary) local air pollution control districts (APCD) programs. While the primary responsibility for stationary sources (including enforcement of state standards) remains with the APCDs, the State can and does provide overall guidance to APCDs on the State's ongoing programs to improve air quality from stationary sources.

In the year the California Air Resources Board was established, the federal government also responded to the increasing national concern about air pollution by enacting the Air Quality Act of 1967. This legislation provided for a national program to control automobile emissions and larger support of state and local programs to control air pollution from stationary sources. The Clean Air Amendments of 1970, which expanded the federal government's role in air pollution, resulted in EPA requiring each state to prepare a State Implementation Plan (SIP). Such a plan was to contain measures to attain the nationally promulgated ambient air quality standards established to protect public health and welfare. EPA was given the authority to prepare and/or enforce the SIP should the State fail to do so.

ARB, with the assistance of the APCDs including the Bay Area Air Pollution Control District, submitted its SIP to EPA in February, 1972, and EPA approved it, with certain exceptions in May, 1972. One of the deficiencies

of the California SIP was that it did not include adequate control strategies for transportation related pollutants. This particular deficiency was common in many SIPs around the nation.

Subsequent to a court decision on this issue, EPA directed the appropriate states, including California, to submit a Transportation Control Plan (TCP) for the auto-related pollutants. The purpose of the TCP was to develop control strategies which would lead to a reduction in transportation related pollutants sufficient to attain national air quality standards. Among the ways in which this was to be accomplished were reducing the number of vehicle kilometers traveled (VKT) and more extensive controls on in-use vehicles (e.g., special maintenance, retrofit).

There were a number of control measures proposed in the TCP which would have had definite land use impacts. They were Parking Management Plans (PMP), used to complement the transportation and carpooling measures, and "Indirect Source" review, aimed at more detailed studies on traffic-inducing facilities such as shopping centers, industrial parks, or schools.

In 1973, as a result of the court decision in National Resources Defense Council v. EPA, SIPs were also required to include a long-term air quality maintenance plan (AQMP) for maintenance of air quality standards. Air quality maintenance requires a comprehensive control strategy approach to the long-term air pollution problems of a region. By necessity, such an air pollution program will include land use and transportation control measures, as well as the regular SIP application and enforcement of technological controls on stationary sources and on the car. The ARB is currently guiding California efforts to develop AQMPs and revise the SIP to demonstrate both attainment and maintenance of air quality objectives.

ARB Policy Formation and Enforcement. The State Implementation Plan is the main Air Resource Board planning document to reflect state air pollution abatement policies. The regulations in the SIP are primarily aimed at carrying out the elements of the federal statutory/regulatory scheme. The SIP also includes the ongoing Air Resources Board programs of auto emission controls and standard setting for stationary and non-vehicular sources.

ARB's enforcement powers include:

1) assume the powers of an APCD if there is a finding that the APCD regulations are insufficient to achieve the air quality standards. Such powers would include the issuance of permits for stationary sources. The ARB can also direct the APCD to correct deficiences in their program;

2) assess and recover a penalty for a violation of a vehicle emission control;

3) eliminate or reduce the amount of funding to an APCD if ARB feels that they are not actively or effectively engaged in reducing air contaminants.

Effect of State Air Quality Controls on Land Use. The status of the state-encouraged air quality controls in 1975 was extremely confusing. The ARB was in its fifth revision of the SIP in order to satisfy national air quality standards. EPA over the past four years had promulgated the earlier mentioned mandatory strategies in the SIP (TCP, PMP, Indirect Source Review) that included a number of land use related controls. Indirect source review, for example, was to be a permit issuing program, most likely administered by APCDs, aimed at eliminating the localized carbon monoxide problem. Permits could have been denied to such traffic generating land uses as shopping centers or industrial parks if such facilities would cause a violation of the carbon monoxide air quality standard. In 1975, EPA suspended the indirect source review regulation pending further Congressional guidance. Similarily, parking management strategies, aimed at controlling traffic generated by parking, were dropped pending further guidance. Recent congressional guidance has leaned in the direction of not requiring any mandatory land use or stringent transportation strategies in SIPs. Instead, states would conceivably have greater flexibility in suggesting air quality control strategies as long as they provide proof that they could attain and maintain the national air quality standards. However, given the stringency of the federal standards, it is difficult to imagine a SIP being accepted that does not include land use and transportation strategies in some form.

Since indirect source review has never been made operational, there have been no enforcement actions to determine how its potential use would impact either growth management or site specific planning activities. For example, it is unknown whether indirect source review would result in shopping centers being disallowed in areas exceeding the federal carbon monoxide standards, or if only additional mitigation measures or design changes would be required to minimize the adverse impacts. An indirect source review that disallowed a downtown office and shopping complex proposed in an area of high carbon monoxide concentration while permitting the same facility at the fringe of the city because of lower CO concentrations would encourage a dispersed employment growth pattern in the region. This would particularly be the case in an emerging area like Sonoma County already faced with strong sprawl pressures and whose public transportation may not provide satisfactory service to induce new commuters or shoppers to ride to more centralized areas.

The equity of the indirect source review to handle such issues would become critical in determining how control affects the size and shape of a region. The above example of high carbon monoxide concentrations would most likely occur in an older, built-up city thereby resulting in those cities being at a disadvantage in indirect source review when compared to with the new and developing communities.

Parking management is aimed at being an automobile disincentive strategy. Such controls as a parking fee structure, restrictions on time of use or preference to multiple occupants are some of the potential elements in this strategy. Parking has typically been controlled locally by parking requirements in zoning ordinances and by controls placed on privately or publicly owned or managed parking lots. Therefore, the impact on employment or population patterns depends highly on whether local governments

agreed or were forced to agree with a region wide planning and compliance approach. A regional growth strategy featuring a strong central city concept serviced by public transit and with limits on parking would face competitive advantage problems if a nearby city placed no restrictions on its own parking. Here again, the impact of parking management on growth would vary based on the level of region-wide enforcement.

Air Pollution Control Districts (APCD)

The air pollution control district is a local government agency and therefore somewhat out of place in a discussion on state agencies. Yet, because of its extremely close connection with the Air Resources Board and the federal air quality programs, it is appropriate to discuss APCDs at this point. The county level air pollution control district was the first state legislatively initiated system to work specifically on air pollution. The APCDs are empowered to enforce the state stationary source emissions standards and can set more stringent standards should they desire. APCDs are also, as part of a basinwide effort, required by state law to establish a coordinated air pollution control plan which can then become part of the State Implementation Plan.

There are two APCDs involved in the Sonoma study area - the North Sonoma Air Pollution Control District and the Bay Area Air Pollution Control District (BAAPCD). (The BAAPCD, strictly speaking, is not an APCD. It was specially created by the State Legislature as a regional special district including all those sections of the nine-county Bay Area that make up the air basin. The BAAPCD has identical powers to all the other APCDs with the exception that it has the ability to tax.)

APCD Policy Setting and Enforcement. Policy setting by APCDs comes in the form of: 1) regulations on stationary source emissions, 2) recommended control measures as part of the SIP and 3) "variances" to the regulations.

The Board of Supervisors of the county serves as the policy making body of the Air Pollution Control Board. The control board for the BAAPCD is comprised of one member from the Board of Supervisors of each county and one city councilman or mayor from within each county.

The regulations serve as the main policy of the air pollution control boards. As an example, some of the BAAPCDs regulations cover:

1. Dump fires and trash burning;

2. Controls on particulate matter, sulfur compounds, lead, nitrogen oxides, asbestos, mercury, odorous substances from industrial and commercial sources, and some forms of incineration emissions. The Ringelmann test, used in evaluating smoke, is used by the BAAPCD for particulate matter. The Ringelmann test will be cited later in the discussion on local planning agency zoning controls; and

3. Storage and use of solvents, paint, gasoline, and ink.

Enforcement of the regulations comes through:

1. Orders of abatement - gives a polluter a period of time to stop a violation;

2. Permits - includes both the authority to construct and the permit to operate;

3. Injunctions; and

4. Misdemeanor penalties.

There is some flexibility in strict regulation enforcement to relieve polluters from "extraordinary hardship." The hearing board, the judiciary of the APCDs, can grant a variance to the regulations and impose other conditions on the polluters - e.g., time limits for compliance, alternative standards.

Impact of APCDs on Land Use Decisions. The potential impact of APCD regulations on land use is their influence on the location of stationary sources, e.g., an existing or new industry. The stationary source regulations concern both the total amount of emissions permitted from any source and the effect of these emissions on the air quality at or near the source location. For example, a new refinery applying to locate in an area of poor air quality could be required to attain a higher level of emission control than if it located in an area of acceptable air quality. If the cost of the additional emission control devices was prohibitive or disproportionate when compared to the other locational advantages of the area, the refinery could settle elsewhere. The land use effect of point source regulations, therefore, can be one of dispersion of industries or other land uses of high emission potential.

State Water Resources Control Board (SWRCB)

California has had a state/sub-state water pollution control system since 1949 (Dickey Water Pollution Act). It was reorganized in 1969 under the Porter-Cologne Water Quality Control Act. Because of California's history of State level concern for water quality, it is not surprising to find that its legislation was a model for the present federal program in that it included both: 1) shifting the emphasis from ambient water quality standards to control of discrete water discharges and 2) preparation of basin (regional) water quality plans.

SWRCB Policy Setting and Enforcement. The SWRCB, consisting of five members appointed by the Governor, is charged with:

1. Formulating and adopting state water quality control policy including that on groundwater, surface water and water reclamation;

2. Determining water quality research needs;

3. Coordinating water quality related investigations of other state agencies;

4. Formulating, revising, and adopting general procedures for water quality control plans as submitted by the regional board;

5. Requiring state and local agency investigations and reports on any technical factors involving water quality control;

6. Allocating funds to regional boards; and

7. Regulating the testing, licensing, and use of materials for cleaning up oil in state waters.

The policy setting comes in a variety of forms including: 1) statewide policies, 2) review and revision of basin plans and 3) establishing priorities and administering the federal and state grants for local sewage treatment and collection systems.

The statewide policies provide guidance to the regional water quality control boards on their preparation of basin plans, and, thereby, provide the basis for SWRCB plan review. These statewide policies include:

1. General principles for the implementation of water resource management programs among which are: a) consolidation of sewerage facilities, b) reclamation of wastewater, c) regional management of water supply and wastewaters, d) prevention of substances not amenable to treatment from entering the sewage treatment systems.

2. A "non-degradation" policy whereby waters of higher quality than state standards should, to the maximum extent possible, remain unchanged.

3. Thermal, ocean, and enclosed bays and estuaries policies aimed at giving specialized water quality attention to the unique circumstances that the subject areas present.

One of the most politically sensitive policy decisions made by the SWRCB is its setting of statewide priorities for the distribution of state and federal sewage treatment grants. Priority setting is important because of: 1) the limited amount of money for such improvements and 2) the linking of population expansion to the adequacy of existing or proposed sewage treatment facilities. The basin plans prepared by each region for the SWRCB indicate the estimated capital and operating costs of needed facilities and the staging program for their construction. Yet, these plans do not set priorities of funding within the region. Priorities are instead established by state regulations to which the regional boards adhere on a project by project basis. The priority list is then submitted to SWRCB for its alteration and approval.

The enforcement powers of the SWRCB include its ability to review and override point source permit decisions made by the regional water quality control boards, and its priority setting power which can be used to ensure modifications of basin plans and/or "201" facility plans.

Influence of SWRCB on Land Use. The powers provided to the State Water Resources Control Board and its regional water quality controls boards, make it now one of the strongest agencies at the state and regional level in shaping regional and local land use. No other agency has the same power to influence growth by controlling the configuration of sewer infrastructure and sewer hook-ups, and the directing of money that controls the quantity and quality of the sewage system to which individual homes or commercial establishments are connected. For example, there are a number of areas within the Sonoma study area that are, or will soon be, faced with growth limitations due to inadequacies either of their treatment plants in meeting State efficient limitations or to the hydrologic limitations that make them unsuitable for septic tanks or cesspools. The regional water quality control board has virtually stopped growth in these areas. The restrictions will be removed only when the appropriate additions are made to the sewage system.

Regional Water Quality Control Boards

There are nine water basins in California, each of which has a regional water quality control board providing sub-state planning and regulatory powers. Like the State Board, regional board members are appointed by the Governor. There are two regional water quality control boards in the Sonoma Study area - representing the San Francisco Bay Region and the North Coast Region.

Policy Setting and Enforcement. The regional boards serve basically as the local water quality planning and enforcement arm of the State Water Resources Control Board. The powers other than planning given to the boards are:

1. The establishing of requirements for all waste discharges, including both those by community sewer systems and point sources not hooked to the community sewer system. Both categories of dischargers must submit a report describing the nature of discharge, including its character, location and volume. If the regional board finds that a discharge violates or will violate a board requirement, it can require the submission of intended remedial actions, including time schedules. The board, however, is limited in its power in that it may not specify the design, location, type of construction or manner by which compliance with State standards may be achieved.

2. The issuing of cease and desist orders for those dischargers who do not comply with requirements. Such an order can require immediate or phased compliance. Court injunctions and civil fines are possible to enforce these orders. Potential discharge violations covered by the cease and desist law include issues of volume, type and concentration of waste.

Effect of Regional Water Quality Control Boards on Land Use. As indicated with the SWRCB, the regional boards' effect on land use can be considerable, particularly with respect to growth management controls.

The effects of hook-up limitations, septic tank restrictions and sewer system quantity and quality restrictions were indicated earlier. In addition, special mention should be made of the possible land use impact of controls on industrial waste sources and stormwater runoff. The basin plans for both regions do not discuss in any great depth the impact of industrial discharges or other point discharges on the "beneficial uses" of nearby waters. ("Beneficial uses" described in the various basin plans include municipal water supply, fish spawning, scientific study, marine habitat, commercial fishing, water contact recreation, agricultural water supply.) This omission was due to the lack of EPA effluent guidelines for most of the discrete industries requiring permits under the National Pollution Discharge Elimination System (NPDES). These standards, when completed, will still require regional interpretation based on the identified beneficial uses within proximity of the discharge. The regional board could be more restrictive than the federal standards if a desired beneficial use at the particular location warranted it. Since both water quality and beneficial uses are locationally varied, they have the potential for creating different regional land use patterns. As an example, an industry located in a city that is upstream from a shellfish bed may face controls that it would not face if located elsewhere in the region.

The industrial point source type of problem did not present itself in the Sonoma Study area due to the area's low level of industrial discharges. Thus, it is difficult to determine how major such a growth issue might be for other regions. Conceivably, the combination of a "non-degradation policy," wide distribution of beneficial uses throughout the region, and pollution abatement costs that are not prohibitive would result in no one area having a competitive advantage over another. Therefore, the importance of point source control in a scheme of growth management could be minimal.

The basin plans pay only modest attention to urban surface runoff. Consequently, the regional boards have no clear policy on the subject matter. This condition was recognized by both federal legislation, and its state and regional implementers, in the required "208" plans, which are to address such nonpoint sources as surface runoff.

The only land use policy implication of stormwater runoff faced by regional boards, occurs when stormwater runoff has infiltrated an existing sewage system resulting in wet weather flows to the treatment facility at levels greater than its capacity to handle them. Unless such infiltration results in a major regional level public health hazard, it would be classified only as medium priority on the state priority list for funding. This priority rating would most likely mean that federal or state money would not be immediately forthcoming and yet still result in a limited growth situation due to the inadequacy of the treatment facility.

A land use control/surface runoff issue of greater significance is that the present methods of measuring dry weather water quality are inappropriate for wet weather. (Dry weather refers to a time period when there

is relatively little rain while wet weather refers to the rainy season.) First, the water quality standards for beneficial uses established in the basin plans have been determined specifically for dry weather flows. The impact of wet weather flows on beneficial uses has not been assessed and therefore standards setting has not been necessary. Secondly, pollutant levels in dry weather flows are usually measured in terms of concentrations that are measures of the amount of contaminants in a net volume of water (e.g., 5 milligrams per liter) thereby taking dilution into consideration. Surface water runoff, however, can cause wet weather concentrations to be lower than those for dry weather because the increase in stream flows more than offsets the increase in contaminants washing into the stream. Yet, the total amount of pollutants entering the water would be substantially higher. This higher total amount of pollutants can have a considerable impact on beneficial uses once they settle in areas of inadequate mixing or movement such as in bays or estuaries. Therefore wet weather measurements should be distinguished from those for dry weather if greater attention is paid to the impact of total pollutants (mass emissions) on beneficial uses.

Office of Planning and Research (OPR)

The Office of Planning and Research is the designated state agency for overall state-level environmental policy planning. Its functions include assistance to and coordination with other state departments and agencies. Perhaps most importantly, its functions do not include any direct implementation or regulatory power.

OPR Policy Setting. The primary activity of OPR related to policy setting is the legislatively required Environmental Goals and Policy Report. The purpose of this report is to provide both coordination and information for the legislature and state agencies, and it does this by presenting all approved state environmental goals. It also provides a 20 to 30 year overview of state growth and development.

The report, therefore, does not set policy. Rather, it compiles the policies from other state agencies. For example, the air and water quality policies of the 1973 report are re-statements of policies set forth in California's pollution legislation.

OPR Intergovernmental Relations. The major role OPR plays in state-level planning is one of coordination and assistance to other state departments, to regional agencies and to local governments. For example, one of its special duties is to help the State Department of Finance in preparing the state budget in such a way that it reflects the statewide environmental goals.

OPR serves as the state clearinghouse for environmental impact reports and A-95 reviews of applications for federal grants to state, regional and local governments. It is also the state level administrator of federal "701" comprehensive planning funds to cities, counties and regional planning organizations.

OPR Effect on Land Use. Because OPR lacks direct implementation or regulatory power, it is restricted in how it affects land use patterns in the state. It relies on altering the policies of other state agencies through various special purpose studies, and on encouraging local government to improve its own ability to prepare the mandatory elements required of each city and county general plan. It has therefore to date played only a nominal role in integrating air and water quality considerations with land use planning.

Department of Fish & Game

Protection and enhancement of the state's wildlife resources is the responsibility of the Department of Fish & Game. To fulfill this responsibility, the Department carries out a wide range of activities, including measures to protect the waters of the State from pollution. The Department receives policy direction from its governor appointed five member Fish and Game Commission.

Policy Setting and Enforcement. General guidance for the Department's policies and activities is provided by the California Fish and Wildlife Plan, which was completed in 1965. The Plan consists of a comprehensive inventory and evaluation of the state's fish and wildlife resources, and it then recommends goals and policies to be followed in order to achieve them. The policies and recommendations include a commitment to actions preserving fish habitats by protecting water quality.

The State Fish and Game Code gives the Department substantial authority to limit water pollution. Besides listing a number of specific substances that are "...unlawful to deposit in, permit to pass into, or place where they can pass into the waters of this State..", the law also makes a blanket statement making it illegal to discharge "any substance or material deleterious to fish, plant life or bird life." Additionally, the Fish and Game Code bans the disposal of vehicle parts or other rubbish within 150 feet of the high water mark of any water body or water course. The Department has the authority to levy fines against offenders and require polluters to remove the contaminating substances from the water.

The Department also has review authority over all actions which would divert or obstruct the flow of any water course or water body, including streams or rivers, or use material from their beds. Further regulations require government agencies, utilities and private individuals or corporations to submit plans affecting designated water courses and water bodies to the Department for review. If the Department determines that the activities will affect an existing fish or game resource, it can impose conditions on the project for their protection. The Fish and Game Code makes special mention of salmon and steelhead resources, and directs the agency in its review of project environmental impact reports to promote measures that expand as well as protect salmon and steelhead resources.

In its water quality related work, the Department of Fish and Game works in conjunction with the various regional water quality control boards. The Fish and Game Code specifically directs the Department to cooperate with and work through the regional water quality control boards in correcting pollution problems. According to interpretations of state law by the Attorney General, the Department has authority to take independent action to apply its own criminal sanctions against polluters. Additionally, the Attorney General has ruled that water quality control boards cannot permit actions that would be in violation of the Code. In the North Coast Regional Water Quality Control Board's jurisdictional area, the fish and game employees serve as field inspectors.

Effect on Land use and Water Quality. The Fish and Game Commission's effect on land use is largely on a site-specific, case-by-case basis. A review of applicable literature did not reveal any cases where the Commission has come into conflict with a regional water quality control board. It appears that every effort has been made to avoid such a conflict. Fish and game habitat is one of the "beneficial uses" considered in setting standards in regional water quality plans.

Energy Resources Conservation and Development Commission

The Energy Resources Conservation and Development Commission was created in May 1974 by the State Energy Resources Conservation and Development Act (Public Resources Code 25000) and became effective January 1, 1975. The Commission is a state level planning and regulatory agency with comprehensive authority to plan for electric energy needs within the State and to preempt, with few exceptions, the certification of all new thermal power plants or electric transmission lines. (In this case, thermal means all those electric generating systems based on heat conversion, which thereby includes virtually all forms of energy generation.) The Commission is part of the Resources Agency. A surcharge on electricity rates pays for its operations.

Policy Setting and Enforcement. The main policy setting device will be a biennial report which includes emerging trends and the level of state and service area energy demands. These demands are then to be re-assessed by the Commission, and it will issue its own statement on future energy demands, taking into consideration growth and development, environmental quality needs, maintenance of a healthy economy and protection of public health and safety. This statement will provide guidance for certification of new facilities.

Enforcement powers of the "Energy Commission" come in the form of a certification program of all new electric generating sites and related facilities. The Commission has the power to override many state and local agency decisions. The override power cannot be used, however, on air or water standards.

Effects on Land Use. The "Energy Commission" was created in 1975 and thus it has not yet developed decisions or plans by which its policies can be assessed. Its powers most certainly can affect such growth management issues as the timing and sizing of additional power sources to a region or community. However, it is too early to tell, for example, if the Commission's charge to seek means of conserving energy will include limits on population until the per capita consumption drops to desired levels.

It is certain that requiring the Energy Commission to prepare the Environmental Impact Reports for all proposed new sites is a step toward ensuring that more than just energy requirements are considered in energy planning.

Department of Transportation (Caltrans)

The Department of Transportation (Caltrans) was created in 1972, in part to meet federal transportation planning requirements. The State Transportation Board was created at the same time. The Board's functions include:

1) review of transportation plans and the adoption of the California Transportation Plan;

2) review of annual budgets for their consistency with the California Transportation Plan; and

3) review of transportation implications of statewide and regional comprehensive general plans, including those for air and water quality.

Means of Policy Setting. Transportation policy for California was provided in the 1972 legislation. Further elaboration on this general legislative policy will be provided when the California Transportation Plan is completed.

The 1972 legislature made a clear policy shift towards environmental considerations when it placed emphasis on:

1) urban mass transportation and interregional high-speed transportation; and

2) a highway system which is compatible with statewide and regional socio-economic and environmental goals, priorities and available resources.

In noting past problems, the legislature stated that "it is the desire of the state to provide a transportation system that significantly reduces hazards to human life, pollution of the atmosphere, generation of noise, disruption of community organization, and adverse impacts on the natural environment" (Section 14000 of Government Code).

The following example was provided by the legislation to clarify the direction for future transportation planning:

> "In some cases, future demands, particularly in urban corridors, may prove to be beyond the practical capabilities of a highway solution; while in other cases, environmental conditions may rule out a highway solution" (Section 14000, Government Code).

Effects on Air, Water and Land Use. The policy relationship of Caltrans and the State Transportation Board to land use, air and water quality will become clearer when the California Transportation Plan is completed. These interrelationships must be considered due to:

1) Environmental Impact Report requirements, and

2) state transportation policy directives requiring the preparation of alternative plans which can be assessed for air and water quality implications.

Yet, the state statute has already come under fire for not placing sufficient emphasis on air quality issues. The Land and the Environment, a publication sponsored by the Planning and Conservation Foundation, questioned if the statue went far enough in air quality issues. The report indicates that the state statute would have been stronger and more consistent with federal regulations if air quality served more as a "constraint" rather than a "consideration."

This concern may have been premature, owing to the State Transportation Board's action on the draft report of the California Transportation Plan. The Board postponed preparation of the final plan due to inadequacies in the draft. The Board determined that many parts of the draft did not comply with sections of the state statutes requiring a clear presentation and evaluation of alternative plans. An alternative that was not in the draft, and one which the Board wanted to see, was one aimed at reducing auto use.

REGIONAL AGENCIES INVOLVED IN AIR AND WATER QUALITY

This next section is concerned with the regional governmental agencies involved in land use, air quality and water quality. Two of the most important of such agencies, the air pollution control districts and the regional water quality control boards, were discussed previously. Two other regional agencies active in pollution matters in the San Francisco Bay Area, the San Francisco Bay Conservation and Development Commission and the regional coastal zone commissions, do not have jurisdiction inside the Sonoma Study area. The three regional agencies that will be discussed are the Association of Bay Area Governments (ABAG), the Metropolitan Transportation Commission (MTC), and the Bay Area Sewage Services Agency (BASSA).

Association of Bay Area Governments (ABAG)

ABAG was the first council of governments in California. Created in 1961, it functions as the only multi-function, comprehensive planning agency concerned with the entire San Francisco Bay region. At present, 85 of 92 cities and 7 of 9 counties in the Bay Area are members of ABAG as voluntary signators to a joint powers agreement.

Policy and Enforcement Powers. ABAG policy is stated in the form of 1) the Regional Plan 1970:1990, 2) additions and amendments to the Regional Plan, and 3) actions by agency committees reviewing grant applications and by staff reviewing Environmental Impact Report documents.

The Regional Plan's policies are concerned with regional growth in the Bay Area and include a city-centered concept aimed at re-building the existing cities and preserving open space between the cities. ABAG has prepared or is presently preparing a variety of regional plan elements aimed at satisfying federal requirements; these include HUD required housing and land use elements and an environmental management element with AQMP and "208" sub-elements.

Effect on Land Use and Air and Water Quality. ABAG has no direct enforcement powers. Any implementation of its policies comes either as voluntary action on the part of member agencies or as a result of A-95 or EIR reviews which alter the initially intended actions. For example, a 1975 ABAG initial review on a "new town" proposal in an area of current air quality problems resulted in the project being postponed indefinitely. Nonconformance with various Regional Plan policies provided part of the reasoning behind the negative comments. The review also indicated that: 1) topographical and meteorological characteristics of the area were conducive to air pollution, and 2) long distance car commute patterns would result from the development due to the lack of nearby jobs and mass transit.

The effects of ABAG air pollution policies on land use would be to encourage a centralized population and employment pattern in sub-regional areas that are serviced by mass transit. ABAG policy is less clear on water quality control and so, therefore, is its related effect on land use. It is expected that these policies will become more specific during the "208" planning effort.

Metropolitan Transportation Commission (MTC)

The Metropolitan Transportation Commission (MTC) was created by state legislation in 1970. It was organized to respond to federal transportation programs and to the state mandate of preparing a regional transportation plan for the Bay Area. It is governed by a 19-member board representing the counties, the state Secretary of Business and Transportation, and the federal Departments of Housing and Urban Development and Transportation.

Policy Setting and Enforcement. The principal policies of MTC are found in its Regional Transportation Plan. This plan, adopted in 1973, considered:

a) ecological, economic, and social impacts of existing and future regional transportation systems; and

b) regional plans prepared and adopted by other organizations.

Its content focused attention on 1) federal, state and local highways, 2) transbay bridges and 3) mass transit systems.

The enforcement powers of MTC are:

1) review and approval of local government and transportation district applications for state and federal transportation assistance to ensure compatibility with the regional transportation plan, and

2) approval of various transportation construction projects - bridges, exclusive right-of-way transit systems, bridge expansions.

Effects on Land Use and Air and Water Quality. The effects of MTC on land use are considerable. It is for this reason that MTC is linked to ABAG through a legal agreement and through a Joint Policy Committee. Its planning and plan enforcement powers are major determinants of regional growth in terms of size, shape and timing. A number of MTC's Regional Plan objectives and policies place particular emphasis on land use and environmental linkages. They include:

1) "transportation programs will be designed to reduce dependence on the automobile as a transportation mode;

2) The speed, frequency and service efficiency of transit shall be increased to enable it to compete with the automobile as a feasible and attractive choice.

3) Pricing mechanisms and other economic incentives and traffic and parking restriction shall be considered for appropriate application to reduce automobile use and traffic congestion and improve access in major urban areas consistent with local and regional interest.

4) Staging of transportation facilities investment shall correspond to staged development of the metropolitan centers in accordance with the ABAG Plan.

5) Transportation program designs and plans shall include estimates of air polluting emissions, so that these plans can be evaluated by air quality standards."

These policies place strong attention on coordinated land use/transportation plans which are aimed at reducing air pollution levels. They also give direction to the use of mitigation measures, including transit and traffic restricting approaches, that could further reduce the potential for air pollution created by the car. Finally, MTC has most recently been working on the Transportation Control Plan portion of the State Implementation Plan for the Air Resources Board. The agency has also been developing parking management guidelines for the Bay Area.

Bay Area Sewage Services Agency (BASSA)

BASSA was created to ensure the implementation of the San Francisco Regional Water Quality Basin Plan. To carry out this function, BASSA

prepared a comprehensive water quality management plan. This plan included:

1) a facilities plan - a system or system for conveyance, treatment, reclamation and disposal of municipal and industrial waste waters, and

2) an implementation plan - an identification of the appropriate local agencies responsible for constructing and operating the water quality control facilities. The implementation plan was to include a timetable for construction and a financing plan.

Policy Setting and Enforcement. BASSA policy setting is made by its 21 member board. The board's policy document is its Regional Water Quality Management Plan which was adopted in December, 1973. The policies of this plan are generally similar to that of the San Francisco Bay Regional Water Quality Control Board. This was to be anticipated because the BASSA legislation requires it to comply with the policies, plans and objectives of the State Water Resource Control Board and its regional boards. In this manner, BASSA's planning is very similar to that of the regional board.

The main difference between BASSA and the Regional Water Quality Control Board relates to implementation powers. BASSA can assume responsibility for construction and operation of a facility: 1) when asked to by one or more sewage agencies, or 2) when there is a finding that a local agency does not wish to proceed or cannot proceed on a proposed facility.

Effect of BASSA on Land Use. BASSA does not have any of the land use powers of either the State Water Resources Control Board or its regional boards. For example, it does not make findings on the quality of sewage treatment from a particular discharge facility and place restrictions on its further use. The only possible effect on land use would be that which would occur as the result of BASSA taking over the construction of a sewage treatment plant that was operating below water quality standards, thereby removing a growth limiting cease and desist order. This event has not yet occurred and its likelihood appears remote.

LOCAL GOVERNMENT LAND USE CONTROLS AND AIR AND WATER QUALITY

The next section on governmental structure analyses the use of land use controls by cities or counties in achieving air and water quality. The land use planning activities presently operating in the Sonoma Study area will serve as the basis for analysis. The regulations studied include General Plans, zoning ordinances, subdivision regulations and grading regulations.

General Plans in California

The California Planning and Zoning Law provides the statutory basis for local government planning in California. It requires each county and city in the state to establish a planning agency whose functions include

the development and maintenance of a general plan. This general plan is required to include the following elements:

1) land use,
2) circulation,
3) housing,
4) conservation,
5) noise,
6) scenic highway,
7) seismic,
8) open space, and
9) safety.

Each of these elements requires a statement of development policies including objectives, principles, standards and plan proposals. The Conservation Element is of particular importance to water pollution because it is required to provide policy on conservation, development and use of natural resources including water, rivers, and harbors. It is also to cover:

(1) The reclamation of land and waters.

(2) Flood control.

(3) Prevention and control of the pollution of streams and other waters.

(4) Regulation of the use of land in stream channels and other areas required for the accomplishment of the conservation plan.

Other general plan elements can also have significance to water pollution control. For example, the Open Space element lists the use of open space for the "protection of water quality and water reservoirs as well as for the protection and enhancement of air quality."

No element is particularly adaptive to air pollution control. Because of this problem, the California legislature in 1972, through Senate Bill 981, requested the development of guidelines for an air pollution control element in the general plans. However, the California Air Resources Board did not recommend such an element because: 1) the required environmental impact report on general plan elements would accomplish similar results, and 2) a local plan air pollution element could not resolve the problems of interregional transport of pollutants.

A planning consultant report, prepared as part of the SB 981 request, found similar problems with an air pollution element. For example:

1) air quality modeling or forecasting could only be accomplished at an air basin level, and

2) interjurisdictional problems of plan development and enforcement would not be resolved.

Therefore, all efforts at creating a separate air pollution element in local general plans have been dropped. Theoretically, the air quality consideration in general plans would come as a result of the environmental impact reports (EIR) on the other general plan elements. (To date, no EIRs for any General Plan and General Plan Element have been submitted in the Sonoma study area.) In addition, total reliance on an EIR fails to recognize the need for local governments to adopt policies on methods of attaining air quality. Conceivably, such policies could be well addressed in the land use or transportation elements. However, because they are not specifically required, local planning agencies have generally not adopted specific air quality policies.

Enforcement of General Plans in California. The general plan has no direct legal effect. It must be implemented by various legal controls including zoning ordinances, subdivision ordinances, and a variety of other ordinances, regulations, and administrative rules. The general plan is also implemented by capital or operating budgets.

California has taken a number of steps in tying the general plan policies directly to implementation. First, it has required that zoning ordinances, open space ordinances, and subdivision and building permits must be "consistent" with general plans. Unfortunately, there has been no clear description of the word "consistent" as to whether it includes the process of zoning, including the attachment of conditions, or simply consistency of the mapped land uses of the general plan and zoning map.

An interesting portion of this legislation is that enforcement of consistency can come through legal action by residents and property owners within the city or county.

The California legislation has required that public works budgets from all city or county departments be reviewed by the planning departments for their conformity with general plans. This requirement must also be met by special districts. While the law is limited in that it does not include operating budgets or require budget "consistency" with general plans, it does provide an initial step towards integrating local policy setting with budgeting.

The Impact of New Forms of Zoning on General Plans. A number of the recent zoning approaches in the Sonoma study area, as in the rest of the United States, have shifted from very rigid and patterned controls to those with increasing administrative flexibility. Planned Unit Development zones, cluster zones, overlay zones, and performance standard zones have shifted the administration of zoning from rigid procedures to those with greater flexibility for reviewing environmentally or socially sensitive geographic areas. This new flexibility is particularly adaptive to the General Plan Policies in that the policies can be applied directly as part of mitigating conditions in the granting of zoning. More complete data on a site can also be provided for an Environmental Impact Report (EIR), which is required in California for most zoning decisions.

For example, a particular parcel of land may not appear to be suitable for housing development from a water quality standpoint due to poor natural drainage conditions which could lead to rapid water runoff and

greater stream pollution. Yet, an adopted general plan policy, included in the Conservation Element, might permit development in such areas when:

1) a detailed site investigation included in an EIR indicates that structural means can be undertaken on the parcel to reduce the pollution runoff problems, and

2) such structural measures (e.g., detention ponds, siltation basins) are included as part of zoning conditions.

The importance, then, of general plans and zoning ordinances in California is that they provide the policy making and enforcement structure by which local level air and water quality land use issues may be addressed. To summarize:

1) the General Plans provide policy,

2) the zoning and subdivision ordinances and building permits provide the framework and mechanisms to enforce the policies, and

3) EIRs provide the technical information by which flexible zoning decisions, based on both policy and site sensitive data, can be made.

<u>Analysis of General Plan Policies for Air and Water Quality in Sonoma County</u>

A review has been undertaken of all General Plans and Plan Elements in the study area for policy statements that are directly or indirectly related to air and water quality.

The documents include:

Sonoma County

- o Statement of goals and policies of the draft General Plan (the statement has not been adopted as of the date of this writing)
- o Plans of unincorporated communities which vary in content from general to specific recommendations

Santa Rosa - General Plan and completed elements

Rohnert Park - General Plan and completed elements

Sonoma - General Plan and completed elements

Sebastopol - General Plan and completed elements

Healdsburg - General Plan and completed elements

Cotati - General Plan

General Plan Policies Related to Air Quality. Few of the plan documents reviewed give much explicit attention to air quality concerns. Only the County, Santa Rosa, Petaluma and Sebastopol make statements that can be interpreted as placing a major policy emphasis on preserving air quality. Some of the other plans make incidental policy recommendations that are specifically tied to reducing pollution or its nuisance effects, but do not make a general commitment to the maintenance or enhancement of overall air quality. All the plans include policy statements, which although not directly related to air quality concerns, are of potential relevance for improving air quality conditions.

Of all the planning documents reviewed, the Sonoma County goal and policy statement puts the strongest emphasis on air quality concerns. It includes a series of well articulated proposals directly addressing the question of air quality maintenance. Its suggestions include support for a land use pattern that minimizes the number of trips and vehicle kilometers travelled, promotion of a transportation system that reduces the number of vehicles, improvement of the efficiency of traffic control systems, regulation of point sources, control of indirect sources and support of emission control device programs.

Some of the General Plan air quality policies of the various cities are quite general. Santa Rosa's Composite General Plan simply calls for, without further elaboration, the application of appropriate zoning standards to control sources of pollution. Sebastopol's Open Space Element recommends cooperation "...with other public agencies in the development of agricultural, industrial, and transportation systems which will minimize air pollution and not result in economic hardship."

Air pollution caused by industries receives the most attention in General Plan policies. Rohnert Park's plan calls for protecting residential areas from the air pollution and other nuisances associated with industrial uses. Healdsburg's plan also recommends reducing industrial/residential land use conflicts, and calls for a solution to the air pollution problems associated with sawdust burning at the sawmills. Petaluma's Ecologic Resources Element, which is a combination of a number of the required Plan Elements, calls for locally adopted performance standards for minimizing smoke, fumes, gases, dust, and particulate matter.

One unique feature of the Petaluma Ecologic Resources Element is the stress it puts on the role of reoxygenation in air quality maintenance. The policy calls for the preservation of water and vegetated areas, and the creation of planted buffer strips along major thoroughfares and around industrial areas for the purpose of absorbing air contaminants.

Policies aimed at reducing the dependence on the car through the arrangement of land uses can also be related to air quality. The City of Sonoma recommends that neighborhood convenience centers be allowed in order to reduce automobile use. Santa Rosa places a great deal of emphasis on creating a strong central activity center and providing housing in close proximity to it. The plan for the Sonoma State University environs includes a variety of policies that emphasize the creation of a high density, pedestrian-oriented community around the new Sonoma State campus. None of these policies, however, were specifically tied to reducing air pollution.

Although only the County explicitly relates its transportation policies to the maintenance of air quality, most of the other planning jurisdictions also make recommendations in these areas that could contribute to the achievement of air quality goals. Both Petaluma and Santa Rosa suggest the expansion and improvement of local bus systems. Rohnert Park recommends that access to arterial streets be controlled in order to improve traffic flow. Virtually all the plans call for the creation of networks of pedestrian ways and bicycle paths.

General Plan Policies Related to Water Quality. On the whole, water quality-related factors receive more attention in the local general plans than do air quality considerations. There is more emphasis on acceptable water quality as a generalized goal and as a result of specific policies. Additionally, the plans recommend a variety of measures that could potentially support water quality maintenance and improvement objectives without explicitly linking the actions to water quality goals. The County and most of the cities identified the preservation of water quality as a general goal to be achieved. The County, Santa Rosa and Petaluma tie the general goal of preserving water quality to the more specific objective of protecting aquatic life in local waterways.

Petaluma, Rohnert Park, Sebastopol and Healdsburg, which are wholly or partially dependent on local wells and reservoirs for their municipal water supplies, stress the need to maintain water quality in order to protect their municipal sources. Petaluma recommends that the land surrounding its reservoirs be kept in open uses and managed to prevent erosion and pollution. In order to do this, the plan suggests use of easements and land use control measures to prevent urbanization. Additionally, management techniques to regulate grazing and control drainage are recommended. Because the watershed lands are beyond the city's own jurisdiction, it is further recommended that all governmental actions affecting the watershed area be carefully evaluated for their impacts. Sebastopol proposes that the area surrounding it be zoned for large agricultural parcels in order to protect groundwater quality and to ensure recharge. The county calls for protection of groundwater and recharge areas, but the specific means of doing so have not been spelled out.

Although none of the plans for unincorporated areas of the County mention the preservation of water quality as a general goal, they do pay attention to the problems of failing septic tanks and the need to protect the groundwater sources of domestic and agricultural water supply. In semi-urbanized areas with concentrations of failing septic tanks, the plans recommend the expansion of community sewage collection and treatment systems. Many of the plans propose that proof of adequate percolation be required as a condition of new rural lots.

Few of the plans reviewed considered the management of natural resources and resource extraction as factors in water quality maintenance. Only the County, Petaluma and Healdsburg specifically recommend forbidding disposal of wastes in streams, floodplains or other areas where water contamination might occur. The County suggests that measures be taken

to regulate forestry, agriculture, and mineral extraction to reduce erosion and protect water quality. The plans for unincorporated areas in forested portions of the County recommend regulation of forestry to prevent land instability and erosion including one proposal that the timing of fertilization be controlled to protect water quality.

Although the increased runoff and soil erosion that often accompany land conversion and development affect water quality, these problems receive no attention in most of the plans. When they are considered, it is often in a somewhat limited way. Santa Rosa, for example, simply calls for the preservation of natural vegetation. Petaluma's Ecologic Resources Element is the only plan with a fairly complete set of recommendations in this area. Beside suggesting replanting and grading plans, it recommends that development be regulated to reduce runoff and that projects that would produce excessive erosion be forbidden.

The plans devote little attention to the potential role of site design factors in contributing to improved water quality. Only the county and Healdsburg call for site plans that minimize runoff. Only the county mentions the provision of on-site drainage improvements, including on-site ponding of runoff in cases where a development would create major increases. The county and Rohnert Park suggest reducing requirements for pavement widths in residential areas, although the intent is to improve the aesthetics, rather than reduce runoff. Many of the plans recommend planned unit development concepts to allow clustering and the preservation of open space, but the water quality benefits are seldom mentioned.

Somewhat more attention is paid to the special problems associated with hillside development, and the implications for erosion and water quality are occasionally cited. The Petaluma and Sebastopol plans, as well as virtually all the plans for the unincorporated areas, call for large lots or otherwise reduced densities in the hillside areas. Santa Rosa, Petaluma, Sebastopol and a few of the unincorporated areas recommend no development at all in areas of especially unstable slopes. Petaluma and Sebastopol suggest that street improvement requirements be modified to reduce cuts and fills. Sebastopol's plan is the only one that makes specific site engineering suggestions by recommending that energy dissipators be required to reduce erosion.

Virtually all of the plans reviewed devote a great deal of attention to the preservation of natural stream channels. In only a few cases is water quality protection mentioned as an objective. Generally, the intent seems to be to preserve the aesthetic qualities of the streamside vegetation. Most of the plans recommend building setback and floodplain regulations to achieve their objectives. Only Petaluma and Santa Rosa go so far as to suggest the purchase of land or easements along the streams.

Evaluation of General Plan Air and Water Quality Policies. Given the recency of the idea that local planning and land use control authority can be applied to the solution of air and water quality problems, and the lack of detailed direction in this area in the state's local planning law, it is no surprise that the plans reviewed tend to be deficient in their treatment of air and water quality issues.

Most of the plans considered here treat air and water quality concerns tangentially, if at all. In few cases do the plans discuss the nature of the local meteorological and hydrological systems, levels and sources of air and water degradation, implications of air and water quality conditions for the community, or the rationale for taking steps to maintain air and water quality. Because the dimensions of the air and water concerns are not treated in a systematic way, the goals and policies that are suggested tend to be quite inconsistent, and there is no basis for determining that they present a coherent program for environmental management.

A similarly, since the specifics of local air and water quality issues are not identified, there is no framework for evaluating the appropriateness of any goals and policies that might be recommended. For example, the plans do not provide enough information to determine whether or not the preservation of streamside vegetation is especially critical for the maintenance of water quality or if other measures would deserve a higher priority.

When the plans did set goals for air and water quality they were most often stated in vague terms such as "maintain air quality" or "preserve the quality of surface and groundwater." In only a few cases is there an attempt to make the goals specific by relating them to tangible objectives such as preserving aquatic life or reducing view-obscuring smog. Even these attempts fail to go far enough, because they do not provide the qualitative or quantitative standards necessary to guide policy selection or measure goal achievement.

In most cases the air goals are not supported by well-defined policies needed to effect their achievement. Most of the policies that are suggested are very general goals, seldom spelling out the specific public actions or changes in procedures, administrative guidelines and regulatory ordinances that might be required.

Air and Water Quality Provisions of the Zoning and Subdivision Regulations in Sonoma County

Local development control regulations can potentially play an important role in mitigating impacts on environmental quality. To determine the extent to which this potential is now realized in Sonoma County, an analysis was made of the zoning, subdivision and grading ordinances and the special growth regulations of the County and each of the municipalities in the study area.

It was found that these local regulations can apply to either air and water quality concerns including some that can be applied concurrently to improve both media. The regulations reviewed include:

- regulation of the magnitude of development
- regulations on the location of new development
- regulations on the intensity of development
- regulations of land uses

- o regulation of site development practices
- o regulation and review of site design

Regulation of the Magnitude of Development

Communities can reduce the potential for additional air and water pollution merely by restricting the total amount of new construction. Limited development could result in fewer cars or industries, with an attendant lower air pollution emissions level or with less urban runoff, erosion and wastewater. Such a limitation is an extreme action which most communities are very reticent to exercise. However, development moratoria and other forms of building permit limitation are becoming more commonplace because of restrictions initiated by regional or state water quality control boards due to inadequacies of the sewage treatment systems. Most cities in the study area have been slow in integrating such anticipated limitations into their zoning ordinances. Petaluma, however, has attained nationwide attention for its efforts in integrating growth restrictions into its local planning controls.

Petaluma has reduced its growth rate by means of its residential development control system. In addition to limiting new residential developent to 500 units per year, the system also apportions the development among the various sectors of the city. This spatial allocation is of interest from both an air and water quality point of view because it disperses each year's construction activity, preventing the erosion, dust and runoff associated with the development process from being concentrated in any one particular location.

Regulations on the Location of New Development

Sonoma County and each of the municipalities control the location of new development with zoning district regulations and annexation and utility extension policies. These regulations and policies can directly or indirectly guide development away from areas where it would be undesirable from a water and air quality point of view. For example, the county, Santa Rosa, Petaluma, Rohnert Park and Healdsburg have special district regulations governing hillsides which establish density levels lower than those permitted in most residential areas. Presumably, one effect of these regulations is to discourage development in hillside areas because they involve high per unit costs for building and infrastructure construction. Because the hillside building that is allowed is guided to the least steep slopes, runoff speeds and the associated erosion are lessened. Additionally, the lowered intensities of permitted development reduce the need for vegetation removal, grading, and the creation of impervious surface thereby reducing the amount of runoff, erosion and dust. Similarly, some of the land use regulations locate new residential growth away from air pollution sources. Zoning ordinances throughout the county do this in a general way by segregating industrial and commericial zones. For example, Petaluma's subdivision regulations extend the principle a bit further, requiring non-residential subdivisions to provide buffering along lot lines bordering existing or potential residential uses.

Regulations on the Intensity of Development

Density and intensity of development are of primary concern to water quality due to the manner in which they influence the amount and quality of urban runoff. Generally speaking, the lower the density and the less the allowed lot coverage, the greater the amount of water available to transport pollutants. The reduction of "impervious surface" -- those surfaces such as roofs, streets or parking lots where there is little rainwater absorption -- is one method to reduce surface runoff pollution.

The residential densities permitted in Sonoma County and its communities vary greatly. In Cotati, Sonoma and Healdsburg, there are residential districts that require an acre or more for a dwelling unit. In Santa Rosa, densities of up to 108 dwelling units per acre are possible. The densities allowed in most residential districts, though, range from 3 to 16 units per acre.

Zoning ordinances of Sonoma County and all the communities except Cotati explicitly regulate the percentage of lot area allowed to be covered by structure. All the jurisdictions considered have provisions in their ordinances that establish minimum building setbacks and yards for most districts. Lot coverage regulations do not provide an absolute limit on the lot area devoted to impervious surfaces because they do not limit such facilities as parking lots, malls, walkways and patios. In practice though, there is a relationship between the permitted percentage of lot coverage and the ratio of pervious to impervious surface in a completed project.

Regulation of Land Uses

The control of specific land uses as a method of reducing contaminants or limiting the exposure of people to pollution has been largely confined to efforts to improve air quality. For example, Petaluma, Cotati and Sebastopol have included special provisions in their zoning ordinances limiting the number of service stations at any intersection to two, and establishing 500 feet as the minimum distance between stations that are not at the same intersection. These regulations have an indirect effect on air quality in that they limit the local concentrations of exhaust gases and evaporated hydrocarbons. Cotati supplements these provisions with a statement indicating that all gas stations must comply with the regulations of the BAAPCD.

A performance standard approach is also used in the review of zoning decisions on industrial land uses. Petaluma has simply adopted by reference the current emissions regulations established by the BAAPCD. The county uses a similar approach in general industrial districts but authorizes the Board of Zoning Appeals to adopt its own standards in light industrial districts. Rohnert Park, Cotati, Sonoma and Healdsburg establish emission standards in terms of Ringelmann numbers which reflect smoke density. In a few communities, the zoning ordinances also establish performance standards for non-industrial uses and districts. Healdsburg's ordinance is the most thorough, including a provison for each land use zone district forbidding uses objectionable because of fumes, dust, smoke, cinders or dirt.

Regulation of Site Development Practices

A number of ordinances of the various jurisdictions in Sonoma County require site development practices that can be used to reduce air or water pollution. They include requirements affecting the land both during and after it is prepared for development.

Efforts to reduce erosion and runoff during development receive attention by most cities, either through grading ordinances or through adoption of the excavation and grading chapter of the Uniform Building Code (1973). All the ordinances require that grading plans must be submitted for review, and they establish standards for excavation, fills and drainage. Some of the ordinances require soil engineering and engineering geology reports. None give any attention to erosion due to wind and its resultant dust as a source of air pollution.

The need to maintain vegetation or replant disturbed areas is also recognized by most ordinances. Replanting is mandated by Cotati's and Sebastopol's subdivision regulations as well as included as a consideration in Sonoma County's site plan review section of the zoning ordinance. Planting is also required on major arterials to buffer or insulate residential structures from noise and high concentration of air pollutants associated with heavily travelled thoroughfares.

Review and Regulation of Site Design

All the jurisdictions include design review provisions in their zoning ordinances. These provisions provide an extra measure of control over the details of building and site design because they require plan review and approval as a condition on obtaining a zoning or building permit is applied for. Typically, the planning staff is authorized to review routine proposals and suggest modifications in design. More significant proposals must generally be referred to a special design review committee or to the planning commission for review. Where there are design review committee, their decisions can be appealed to the planning commission. Planning commission decisions, in turn, can be appealed to the city council (or board of supervisors in the case of the county).

There is wide variation in the kinds of design information required to be submitted, and the criteria established for evaluating proposals. Generally, the requirements and standards set reflect the purposes the design review provisions are intended to achieve. In most cases, the primary objective is to promote design which harmonizes with the project's surroundings. The design review procedures, although at present used almost exclusively for aesthetic considerations, do provide sufficient breadth for site conditions that could improve air and water quality.

For example, Santa Rosa'a, Petaluma's, Rohnert Park's and Sebastopol's design review criteria touch on water quality related factors only to the extent that they require landscaping plans, tree preservation and consideration of impacts on natural groundcover. The City of Sonoma's

design review provisions are also primarily aesthetically oriented, but they do leave the way open for evaluation of water quality factors in that they call for consideration of "...the effect on trees, water courses, and other natural features of the site." Of all the design review provisions, the County's is most specific in its regulations requiring bicycle paths to be created. The design review requirements of the zoning ordinances could be used to improve the arrangements for pedestrian circulation. The County, Santa Rosa and Healdsburg ordinances, in fact, specifically require applicants to indicate the provisions being made for pedestrian circulation.

The planned unit development concept, which is authorized by most of the zoning ordinances in the study area, also contributes to reducing auto dependency. Sonoma County's and Petaluma's planned unit development requirements specifically call for integrated planning of vehicular and pedestrian traffic. In Santa Rosa and Petaluma, the planned unit development regulations allow for mixed land uses, which could reduce the need to travel. Santa Rosa's ordinance makes it clear that one of the intentions of the PUD option is to allow residential and commercial uses to be located in proximity to one another.

Santa Rosa, Rohnert Park and Cotati allow developers of planned unit developments density bonuses of 10% to 35%. Besides encouraging the use of the PUD concept, these density increases also contribute to the creation of pedestrian oriented and transit supporting environments.

<u>Evaluation of Zoning, Subdivision and other Land Use Regulations</u>. Because the general plans of the various jurisdictions do not contain a systematic and comprehensive strategy for air and water quality improvement, it is no surprise that such an approach is not reflected in the ordinances.

To a large extent, the ordinance provisions that affect air and water quality are primarily oriented to some other purpose. For example, the controls over development intensity are generally intended to regulate density and prevent crowding and congestion. Their use as a means of reducing runoff is only a side-effect. Similarly, street design principles included in the subdivision ordinances are primarily intended to insure safe, smooth traffic flow rather than to reduce vehicular emissions.

Because air and water quality factors remain secondary considerations in the ordinances, they often receive only cursory treatment. For example, the hillside regulations contained in many of the zoning ordinances emphasize reduction of densities, but do not go into detail in specifying design measures to be taken or standards to be met in limiting runoff and erosion. The grading and drainage related ordinances which incorporate the Uniform Building Code grading provisions are very thorough and detailed, while others are considerably less complete in their coverage and provide fewer technical standards to guide their application.

TABLE IV-2

APPLICABILITY OF DESIGN REVIEW REQUIREMENTS IN SONOMA COUNTY

JURISDICTION	WHEN DESIGN REVIEW REQUIRED	DISTRICTS	USES IN DISTRICT FOR WHICH DESIGN REVIEW REQUIRED
Sonoma County	at time of application for zoning permit or building permit	Unclassified Agricultural Residential Recreational	apartment development with 4 or more units
		Commercial Manufacturing	all uses
Santa Rosa	zoning permit, use permit, building permit	all districts	all uses except single family dwelling units and their accessory units
Petaluma	zoning permit	all districts	all uses except a single family dwelling unit or a single parcel
Rohnert Park	building permit	all districts	all uses
Cotati	building permit	Architectural Design Control combining Districts	all uses
		all districts	"certain uses... which would have ...substantial adverse effect upon the surrounding environment and character of the city..."
Sonoma	zoning permit building permit construction permit	single family duplex residential	all conditional uses
		multiple family intensive multiple family	all projects with 2 or more units

TABLE IV-2 continued

JURISDICTION	WHEN DESIGN REVIEW REQUIRED	DISTRICTS	USES IN DISTRICT FOR WHICH DESIGN REVIEW REQUIRED
Sonoma (continued)		residential hill-side preservation mobile home park industrial park wine production all commercial districts historic conservation combining	all uses
Sebastopol	building permit	duplex residential high density mulitple residential low density multiple residential	duplex or apartment buildings
		administrative and professional office all commercial industrial	any commercial building
Healdsburg	zoning permit building permit	all agricultural districts	all conditional uses
		all residential districts	all uses except single family dwellings, duplexes, and multi-family dwelling with 6 or fewer units, unless more than 3 permits are to be requested for a single block during the course of the year
		all commercial and industrial districts	all uses

Some concerns that are of potential importance for air and water quality are left virtually unregulated. For example, although urban runoff is increasingly seen as a significant source of water pollution, none of the ordinances reviewed set specific limits on the amount or character of runoff from a site during construction or after completion. Other considerations that have been neglected by the ordinances include:

- o tying approval of direct and indirect sources of air pollution to an emission density analysis
- o relating the approval of critical receptors (e.g. hospitals, rest homes, housing for the elderly) to expected air quality conditions
- o developing special design criteria for activity centers to encourage the creation of high intensity pedestrian and transit-oriented environments

Setting performance standards for emissions from industrial uses is one of the few areas where the communities have directly addressed air quality concerns. Ironically, many of these standards are somewhat meaningless. Some of the standards are in conflict with State law and the regulations of the BAAPCD. The State establishes Ringelmann number two as the maximum permitted opacity for smoke emissions, and the BAAPCD is even more restrictive, establishing Ringelmann number one as a maximum. In spite of these limits, a few local ordinances in Sonoma County state that emissions as opaque as Ringelmann numbers three and four are permissible. Many of the provisions governing emissions are expressed in broad terms (e.g.: "No use...which creates any emission which endangers human health, can cause damage to animals, vegetation, or other property..."). Because these provisions have no explicit operational definition, they are difficult to administer and enforce. The primary utility of these blanket statements is to serve as a record of public intent that can be cited when legal action is taken to abate nuisances.

One of the features of the ordinances that has a great potential for dealing with land use related air and water quality controls is the design review procedures established by all the zoning ordinances. As the earlier description notes, the primary orientation of these procedures is most often to ensure improved aesthetic qualities. However, some of the communities have begun to apply them to achieve functional and environmental objectives as well. This is a trend that could be developed in a way that enables design review to address air and water quality related factors in a direct and meaningful way. The fundamental charge that is needed to guide design review in this direction is to develop the underlying understanding of the local air and water quality relationships; in this manner, broad community policy and guidelines can be developed, the information needed for review can be specified, and the criteria to be used for project evaluation can be identified.

LOCAL AGENCY FORMATION COMMISSION (LAFCO) AND SPECIAL DISTRICTS

This section on governmental structure reviews the role of the Sonoma County LAFCO and special districts in air quality, water quality and land use control.

Local Agency Formation Commission

The Local Agency Formation Commission is a county-level independent regulatory body responsible for controlling the formation and expansion of local governmental units in all areas of a county. Creation of the commission was mandated by the Knox-Nisbet Act, and its powers were expanded by the District Reorganization Act of 1965. The intent of the legislation was to reduce sprawl and promote the orderly provision of services. The Sonoma LAFCO is composed of five members: two members of the County Board of Supervisors, two members of the city councils (chosen by the mayors of the cities in the County), and one member representing the general public (chosen by the other four members.)

The Commission reviews and approves (with or without amendments) or disapproves all proposals for:

Cities

- incorporation
- exclusion of territory
- disincorporation
- consolidation of two or more cities
- development of new communities
- annexation of territory

Districts

- formation of special districts
- detachments
- dissolutions
- mergers
- reorganizations
- consolidations
- annexation of territory

In reviewing proposals submitted to it, the Commission is required by law to consider a wide range of factors including:

- population, land use, assessed valuation, drainage patterns potential for growth

- need for organized community services, present cost and adequacy of governmental services and controls in the area, future needs for such services, probable effects

- conformity with comprehensive, sub-area and functional plans

- sphere of influence.

Under State legislation passed in 1972, all LAFCOs are required to designate "spheres of influence" for governmental units in each county in the State. Essentially the spheres of influence are intended to

define the ultimate physical boundaries of the various cities and special districts. To accomplish this, "ultimate" spheres of influence will define entities that are physically separated from each other by areas of unincorporated territory.

Effects of LAFCO's on Air and Water Quality. Because the Sonoma County LAFCO has no written criteria for decision-making, it is difficult to make a definitive assessment of the implications of its activities for air and water quality. Based on the kinds of authority the LAFCO does have, it can be hypothesized that it influences air and water quality to the extent to which it:

- promotes orderly urban expansion that creates compact communities which minimize travel demands

- directs municipal and service district expansion to the most appropriate lands, avoiding areas of steep slopes and easily eroded soils

- permits annexations or allows formations of special districts in areas where community sewer service is needed to correct water quality problems due to concentrations of malfunctioning septic systems

- relates the expansion of municipalities and special districts to their capacity to treat the wastes associated with the increased development that could result.

The Sonoma County LAFCO's present operating style is strongly oriented to coordination. The existence of unresolved conflicts between city and county development policies and the fact that the County's General Plan has not yet been adopted account for the reason that the LAFCO has yet to define spheres of influence but has focused on coordination instead. One of the primary strategies being used to promote coordination between the various governmental units is the creation of a city-county Planning Policy Committee (PPC), a mini council of governments, to serve as a forum for the discussion of development issues. The County and local planning directors have been organized by the LAFCO to serve in an advisory capacity to the PPC.

The Sonoma LAFCO has also started to carry out studies aimed at rationalizing the provision of government and services in sub-areas of the County that are now served by complicated overlays of service districts.

Special Districts

The governmental picture in Sonoma County, as in other California counties, is complicated by the existence of a multitude of special service districts. These districts are essentially limited purpose governments established to carry out specific functions within their jurisdictions. Under state law, districts can be established for a wide

variety of purposes. Examples of the types of districts authorized include community services districts, water districts, fire protection districts, sanitary districts, flood control districts, recreation and parks districts, hospital districts and mosquito abatement districts. The districts have the authority to accept grants and contributions, issue bonds, impose charges and taxes, provide services, construct improvements, and in a few cases, issue use permits and regulate land use activity.

Because of their ability to affect water quality and the general pattern of growth, the degree to which the policies of various districts are compatible with those of other governmental units is of critical interest. To some extent, the sensitivity of a district to the policies and concerns of other governmental entities is determined by the composition of its board of directors. Presumably those districts governed by a Board of Supervisors or boards composed of county supervisors and municipal officials are the most attuned to the larger countywide regional policy issues. Boards that are appointed or directly elected are less likely to identify quite so closely with the concerns of the other governmental bodies.

The composition of a district's governing body is determined by the state enabling laws. Under the state codes, County Service Areas are always governed by the board of supervisors while Community Service Districts can either be governed by the supervisors or by an elected board. The various water districts tend to have boards that are separate from the board of supervisors: the Municipal Water Districts and the California Water Districts have elected boards; the boards of County Water Districts can either be appointed by the supervisors or elected, and County Water Works Districts are given the option of having the board of supervisors act as their board or having an elected board. Two of the sewer districts (Sanitation Districts and Sewer Maintenance Districts) have governing bodies consisting of either the board of supervisors or the supervisors and other elected officials. The boards of County Drainage systems always consist of either the board of supervisors or a mix of supervisors and city councilmen. Water Replenishment and Resource Conservation Districts both have elected boards.

In Sonoma County, the special districts vary in size from maintenance districts serving a single subdivision to the County Water Agency which encompasses the entire county. For the most part, Sonoma County's districts provide services in unincorporated areas, although there are a few districts that do include incorporated territory within their boundaries. Each of the districts has a governing body to establish policy. The composition of this body varies from district to district. In a large percentage of the districts in Sonoma County, the Board of Supervisors serves as the Board of Directors. In the other cases, the governing boards are either appointed by the supervisors, or directly elected.

The procedures to establish the various districts are generally similar. In most cases, application must be made to the Local Agency Formation Commission and its approval obtained. Generally, formation proceedings can be initiated by petitions signed by a percentage of registered voters or land owners in the area being considered for inclusion in a proposed district. If a sufficient number of signatures is obtained, the County Board of Supervisors convenes a public hearing to allow discussion of the matter. Based on the hearing, the Board can either terminate the formation proceedings or give the boundaries and functions of the proposed district precise definition and put the question up to a vote. The most common procedure is to allow the voters or property owners in the area within the proposed district to vote on the matter, although in some cases the Board can decide the question for itself. If a district wishes to take on new functions, approval by the Board of Supervisors is mandatory.

Effects on Air and Water Quality. The special districts have a variety of potential effects on air and water quality. In providing sewage service, controlling storm and waste water, replenishing groundwater, restricting use of on-site sewage disposal and providing for street sweeping, some of the districts have a direct effect on water quality. Many of the districts provide services such as water and sewer which make possible urban levels of development in unincorporated areas, indirectly affecting air quality. A brief discussion is provided here of those districts authorized under California statutes to carry out these functions. Not all of the districts described exist in Sonoma County.

Sanitary Districts and County Sanitation Districts focus most sharply on water quality issues. Besides being able to construct and operate systems for the collection and treatment of storm waters, these two districts can also: 1) establish refuse disposal systems, 2) make and enforce regulations for street cleaning, 3) compel connection with the district's sewers and storm drains and 4) prohibit the use of cesspools, septic tanks, and private drainage systems. The last two of these powers provide the special district with a form of land use control that can shape the urban pattern in that particular section of the county.

County Service Areas and Community Service Districts have a considerable amount of potential for addressing water quality problems. Yet this aspect of their operation is not particularly well focused because of the wider spectrum of functions they are to provide for an unincorporated area. Of the two, the County Service Areas have the broadest authority, in that they are allowed to provide the same services as the county. Both district types can collect and treat sewage waste and stormwater, provide for drainage, and collect garbage and refuse. However, unlike the Community Service Districts, County Service Areas can also carry out street sweeping and soil conservation activities.

There are four different types of water districts in California. Each is allowed to establish and operate facilities for the collection, treatment, and disposal of sewage, waste, and stormwaters. On the

whole, the legislation which established these districts does not emphasize pollution-related concerns. The primary exception is the California Water Districts, which have the authority to declare cesspools and septic tanks to be public nuisances, and to require their abandonment in favor of hookup to public sewer systems. The California Water Districts and the County water Districts also have power to prevent actions that interfere with the natural flow of water - a factor that could be related to water quality in some specific situations. Therefore, some water districts are vested with land use controls aimed at protection of water quality.

There are several other types of districts that are not involved with sewer service or otherwise explicitly linked to water pollution concerns, but that do have some authority that could affect water quality. Water Replenishment Districts are established to replenish groundwater. They can buy and sell water, distribute it, and spread, sink or inject it. County Drainage Districts are established to control storm and waste waters and protect property from storms. They can conserve storm and waste waters or cause it to percolate. County Flood Control districts can provide for the improvement of rivers, prevent their obstruction, and protect and preserve their banks.

Resource Conservation Districts (RCD) deserve some special attention. These districts were formerly known as Soil Conservation Districts, but 1971 amendments to the California enabling legislation broaden their scope. These districts are required to develop plans and programs concerned with soil and water conservation, farm irrigation and land drainage, erosion control and flood prevention, and community watershed protection. An interesting part of the RCD legislation is that the plans that are required must be "consistent" with County general plans. This is the only case where the activities of special districts are required to be integrated with local government planning. Cooperating land owners can have the district pay for conservation improvements on their land, but they must abide by specific cropping, tillage, and range practices identified in the plans and programs.

DEFICIENCIES OF THE GOVERNMENTAL STRUCTURE FOR POLLUTION CONTROL

If looked at in its aggregate, the California governmental structure for resolving air and water pollution problems would appear to be most laudable. It is so vast in terms of agencies and legal mechanisms that it would appear that no pollution problem can go undetected or unabated. Yet the structure has many shortcomings due to its complexity and its failure to recognize the roles which all levels of government can play in environmental protection.

The major deficiences in the area of governmental structure are:

1) lack of integration of air and water policies and actions with those of other functional planning elements, e.g. transportation, urban design, natural resources, housing, agriculture,

2) lack of integration of policies and actions by the different governmental agencies that affect air and water quality,

3) minimal involvement of local government in the federal and state schemes for planning and enforcing pollution control strategies,

4) lack of consistent review or appeal procedures, and

5) frequent policy setting that is too vague for judicious enforcement.

Lack of Policy Integration

The reasons for the lack of both functional and jurisdictional policy integration relate to the nature of governmental structure in California concerned with environmental quality. The creation of unilateral air and water quality planning entities at both state and substate/regional levels, without sufficient attention to their relationships to other forms or levels of planning, is the main reason for the lack of policy integration.

Local government is the only level of government in California in which there is multi-functional planning combined with enforcement. The state mandated general plans require cities and counties to formulate policies that implicitly require compromises between the potentially competing functional elements that are also mandated as part of the general plans. For example, the land use element policies are developed under the same planning framework as those for circulation or water quality. Once the element policies are created and adopted, local government is required to enforce them with consistent sets of zoning or subdivision controls.

Multi-functional, comprehensive planning does occur in California at the regional level through councils of government like ABAG. Yet, the councils of government have only minimal enforcement powers and are therefore less effective in accomplishing integrative plan enforcement.

At the state level, the Office of Planning and Research has a general charge to conduct and coordinate comprehensive planning but has a very explicit constraint on enforcement powers.

Other state and regional agencies, including those concerned directly with air and water quality, have wide ranging and very powerful enforcement powers, including those that can greatly change land use patterns. However, their policy setting is quite narrow. (It is interesting to note that the recent state legislation for the historically older state transportation function requires more integrative and comprehensive planning than that for many of the more recent State environmental agencies.) Hence, it is not surprising to find that the more narrow perspective filters down to some of the

detailed project planning as represented in the following quote from an EIR for an expanded treatment plant in Sonoma Valley under the "201" program:

> "Growth inducement has frequently been misinterpreted with regards to wastewater treatment facilities. Inducement implies stimulus or incentive to promote development and its associated population growth. Treatment facilities do not in themselves promote growth. However, if the treatment facilities are inadequate either due to capacity or treatment level, they can be growth-limiting."

The above comment on the growth-related effects of a treatment facility presents a correct picture when read in isolation of regional and statewide planning and budgeting considerations. But when read in light of the large regional demands for limited state and federal financial assistance, this passage reveals a lack of recognition that growth inducing and growth limiting are one and the same.

The absence of policy and enforcement integration has two impacts. First, it makes it extremely difficult for policy makers to assess the combined effect of all expenditures or controls on the achievement of air or water quality objectives. It becomes difficult to answer questions about cost-effectiveness of the different steps being taking when one cannot adequately assess the effect of overlapping or counter-productive actions. Secondly, it makes government vulnerable to charges from industry or commerce that additional costs are being borne by the private sector without adequate justification. Additional, needed controls could well become politically unacceptable because their benefits cannot be adequately substantiated.

Minimal Local Government Involvement

Previous federally-initiated air and water quality planning efforts have often been described as "bottom-up." This refers to the preparation of detailed regional plans which are then forwarded to the State for statewide consideration prior to being submitted to the federal level.

Unfortunately, this form of planning did not really start at the bottom because it neglected the role of local government during the development of environmental quality strategies. The rationale for the omission, although not readily apparent, might possibly be that:

1) the problems of air and water pollution are traditionally classified as "regional" in nature,

2) the involvement of numerous counties, cities, and special districts in environmental strategies would present far too complex a management system for planning and enforcement within the statutory timetables, and

3) the lack of the appropriate level of staff expertise at the local governmental level to cope with either the technical subject matter of pollution or the complicated elements of the federal regulatory scheme.

Based on this study's review, it is apparent that the failure to include local government specifically in the federal and state planning and regulatory scheme has resulted in a number of negative consequences.

First, this omission failed to recognize adequately the strength of local government in comprehensive planning and plan enforcement. Comprehensive planning is an area of local government activity which, since the days of urban renewal, has been given considerable federal encouragement. The local level is also the jurisdictional level where some of the greatest innovations have been made in both the content and the form. Certainly, the Petaluma growth control efforts give evidence to integrative planning of such concerns as population growth, environmental improvement and housing considerations. The current emphasis on developing new methods for site-sensitive, environmental policy interpretation again demonstrates the advancements local government is making on land use planning. Therefore, any new regional or state environmental planning and regulatory scheme which deals with land use decisions and does not directly involve local government can be both duplicative and irritating to local planning efforts. Some of the present federal guidance for the preparation of "208" plans has recognized this importance of local government involvement and has encouraged those preparing the plans to give priority attention to resolving intergovernmental issues.

Secondly, the usurping of local government land use control powers can and has alienated local government. When this condition is combined with earlier frustrating pollution abatement efforts, as has been the case in much of the municipal involvement of "201" facilities planning, it is not surprising to find the following quote from "Problems of Municipal Doers in Implementing P.L. 92-500" Report to the National Commission on Water Quality (September, 1975):

> "Many municipal doers, from large but especially small municipalities, are baffled and sometimes angered by the new coordinative mechanisms, administrative burdens and constant form-filling and scheduling involved. They find that the roles of each level of governmental - Federal, EPA regional, State, substate regional and local -- which are different for each major water pollution control function, are frequently overlapping and constantly changing. For these reasons alone, some municipalities have concluded at this point in time, as one municipal doer in Knoxville, Tennessee, that "the passage of P.L. 92-500 has been a decidely mixed blessing." (p. V-14)

Third, the lack of a structured yet flexible system of local government involvement with state and regional levels has resulted in self-initiated but incomplete environmental planning efforts by local government. The

Sonoma study certainly points to the desire on the part of local planning to respond to the public concern for environmental improvement. It also highlights the fact that a number of creative efforts have been undertaken to solve pollution problems. Yet, this desire is hampered by the lack of overall guidance as to the amount and type of land use control effort that is necessary to satisfy both regional and local contaminant abatement needs. A uniformity or consistency of effort by all local jurisdictions in the region is also lacking.

Lack of Consistent Appeal or Review Process

Another finding from the study is that the environmental decisions lack a consistent review, appeal or adjudicatory process. The main concern because of this lack is that the decisions that emanating from review or appeal process often form a new level of policy.

There are a number of different types and reasons for the existing review or appeal process. First, there is the review/appeal process of the state agency over its subordinate regional agency. This is the case with both the Air Resources Board and the State Water Resources Control Board over the air pollution control districts and the regional water quality boards, respectively. The state boards' powers allow them to override a regional boards' decision on a regulation or a permit issuance if it does not meet state standards or if a variance is inappropriate.

A second type of review authority is that of ABAG's A-95 responsibility. Policies that guide this review include those found in ABAG's Regional Plan and those developed on an ad hoc basis if not adequately covered in the comprehensive regional plan.

A third review comes through the environmental impact report process. EIRs are available for both public and private groups and individuals to review. The limitations of this process are well known. Basically, environment impact reports simply report conditions and are not statutorily required to alter the proposed plan or project based on the report findings.

A fourth form of appeal/review comes in the form of hearing boards that can grant variances to the normal regulations. The main reason for appeals is that a particular control brings about an alleged hardship. The zoning boards of appeal and the air pollution control district hearing boards have this form of review.

A final form of appeal/review is through the courts. Traditionally, appeals through the legal system on planning decisions have been on issues of due process and compliance with particular planning legislation or ordinances. However, the recent requirement of consistency between general plans and zoning may lead to direct judicial interpretation of general plan policies to ensure consistent enforcement actions.

Vague Policies

A final conclusion that can be drawn from the review of agencies concerned with air and water quality is one that can be directed at many other agencies involved in planning. Many of the present policies that have been adopted at all jurisdictional levels and pursuant to various land use and environmental issues do not offer the decision makers - and the communities they serve - a clear set of enforceable choices. Too frequently they are stated in such general terms that they offer little guidance for directing improvement actions. The policies described earlier under the local general plans provide numerous examples of environmental policies so vague that their effectiveness can not be measured. The result of such general policy setting is:

1) confusion and inconsistency in enforcement;

2) appeals or law suits because enforcement is either too severe or too lax; and

3) inability to determine whether the policy can be realistically used to achieve some quantifiable end.

CHAPTER V - DESCRIPTION OF STUDY TECHNIQUES

Based on the review of the earlier environmental studies described in Chapter Three, the Sonoma Study directs its attention to determining 1) the influence of urban spatial patterns on air and water quality and 2) the relative effectiveness of specific urban spatial patterns and the corresponding land use controls necessary to create such patterns, in attaining and maintaining air and water quality objectives. The analytical approach used to address these questions is the development of alternative land use patterns that can be evaluated by simulation models for their air and water pollution impacts.

This chapter presents a description of the methods used in: 1) developing alternative land use growth patterns, 2) predicting water quality conditions and 3) predicting air quality conditions. The study techniques are presented in an abbreviated format. A more technical discussion on the air and water modeling efforts is presented in Appendices B, C, D, E and F.

ALTERNATIVE LAND USE GROWTH PATTERNS

The primary purpose for developing the land use alternatives is to present a range of growth patterns for testing the relationship between land use configuration and intensity and the resulting air and water quality (Appendix B).

Nine growth alternatives are developed to represent different combinations of population size, urban spatial pattern, land use density and land use type. These alternatives are described later in the chapter.

Two different County populations are used, based on projections to the year 2000. The 1973 County population of 226,000 provides a benchmark for further analysis and is therefore described as Base Year. The California Department of Finance D-100 projection (assumes a fertility rate of 2.45 children per woman and a net in-migration of 100,000 persons per year to California) of 478,000 population for the year 2000 in Sonoma County, is used as one level. The second projection figure is 630,000, based on ABAG's "Gronorth" alternative which assumes major regional development in the northern counties of the San Francisco Bay Area.

Total county employment estimates were derived, by the University Research Center consultants, as part of the Sonoma County General Plan process. The total employment figures were disaggregated by employment sub-categories (e.g. basic industry - agriculture, manufacturing, basic insurance, local serving - retail, services, local finance and insurance, construction).

The population and employment totals are then converted into their areal equivalents in the form of hectares of residential, commercial and industrial land use. The categories and densities of land uses are selected in a manner that ensures compatability with the existing County land use information and the air and water model requirements. Table V-1 indicates the categories used in the study and their County land use equivalents.

The next step in creating the different growth patterns is to distribute the land uses according to different assumptions on regional and urban development, including:

1) single, central city development versus multi-city development,

2) concentrated development in the core of the city versus development spread throughout the city, and

3) high density development versus low density development.

The General Plans of the Sonoma County cities were used to the fullest extent possible in determining probable future land use locations.

The final step in the preparation of the growth alternatives is the overlaying of a one kilometer grid pattern on the development patterns to determine the percentage of each land use in each cell. There are a total of 920 grid cells in the study area. The land use information for each grid cell was then transferred to a computerized file system for use in both the air and water quality modeling.

There are a variety of reasons that a one kilometer grid pattern was selected. First, since area-source air quality models use a square (or rectangular grid), the square grid cell provides the advantage of easy conversion to model needs that could not be provided by other data units such a census tracts or traffic zones. Secondly, the size is a maximum unit for carbon monoxide analysis because averaging of pollution concentrations over larger cells has the effect of diluting the emissions from certain traffic areas. Thirdly, the one kilometer grid cells can easily be combined to make up the larger hydrologic sub-areas that serve as the basic units for the study's surface runoff modeling. The number of grid cells per hydrologic sub-areas in the study area range from seven to forty. The need to combine many cells means that the detailed land use information derived per grid cell is frequently generalized when used in the runoff model, a point that is important for those wishing to undertake similar studies. A land use system that provides for many land use categories and great spatial detail can provide for far greater resolution than is required for surface runoff modeling.

The following section of the chapter provides descriptions of each of the alternative land use growth patterns. Table V-2 indicates the population distribution in the different land use alternative. Figures

Table V-1

Land Use Classification System

Base Year (1973) Land Use[1]	Land Use Alternatives
Single dewlling	Residential-Low Density 10.8 DU/hectare (5 DU/acre)
Multi-dwelling	Residential-Medium Density 32.6 DU/hectare (15 DU/acre)
	Residential-High Density 69.5 DU/hectare (32 DU/acre)
Commercial	Commercial - City Centered[2]
	Commercial - Suburban[2]
Industry, non-urban industry, transportation and sand	Industrial
Open Space	Grazing/Open Space
Agriculture: orchards and vineyards	Agricultural - orchard/vineyard
Agriculture: field crops and grain	Agricultural - truck crops/field crops
Wetlands	Wetlands

[1] U.S. Geological Survey, Geographic Applications Program, land use map of Sonoma County, 1:62,500, 1972 (from unpublished open file)

[2] The "City Centered" versus "Suburban" distinction is made for water model purposes. The assumption is that the "Suburban" Commercial land will have less impervious surface coverage due to locational and costs advantages not shared by "Centered" Commercial.

TABLE V-2 POPULATIONS OF THE LAND USE ALTERNATIVES (in thousands)

	Base Year (1973)	Santa Rosa Centered (2000)		Urban Centered (2000)		Suburban Dispersed (2000)		Rural Dispersed (2000)	Continuing Trends (2000)	
County Total	226	478	630	478	630	478	630	478	478	630
Santa Rosa	60	215	306	110	151	150	250	75	145	196
Petaluma	30	60	79	92	126	79	91	38	65	97
Rohnert Park	9	42	55	40	55	48	55	12	48	60
Healdsburg	6	11	14	33	45	21	25	7	9	15
Sonoma	5	12	16	27	35	25	30	6	10	15
Sebastopol	4	11	14	33	45	21	25	5	7	10
Cotati	2	9	12	15	20	13	18	3	8	12
Other County Cities (not in study area)	3	5	8	15	27	8	10	4	8	9
City Total	119	365	504	365	504	365	504	150	300	414
Community Total	22	28	32	28	32	28	32	28	48	76
Rural Total	85	85	94	85	94	85	94	300	130	140
% of County in Cities	53	76	80	76	80	76	80	31	63	66
% of County in Communities	10	6	5	6	5	6	5	6	10	12
% of County in Rural	38	18	15	18	15	18	15	63	27	22
% of City Total in Santa Rosa	50	59	61	30	30	41	50	50	48	47

V-1 to V-5 are schematic representations of a selected group of the land use alternatives. The shaded circles show the populations of each of the cities and rural areas in the study area. The larger circles surrounding the population circles indicate the area of each city occupied by residential land. By comparing the relative sizes of the two circles, one can get an indication of the density in each city in each alternative. The larger the white circle is, relative to the shaded circle, the lower the density. The density is high when the two circles are similar in size, as in the Urban Centered illustration.

It must be emphasized that these are only schematic illustrations. The actual land use alternatives consist of very detailed sets of land use data specified in the form of hectares of each of 10 land use types in each of over 900 grid cells for each alternative. The locations of the circles shown on Figures V-1 to V-5 are only rough approximations of where the cities are and should not be taken literally.

Santa Rosa Centered (SRC) Alternatives: 478,000 and 630,000

The intent of the Santa Rosa Centered alternatives is to create a growth pattern in the County which is dominated by the City of Santa Rosa and where most of the growth is urban and compact in nature. Santa Rosa is the center of both population and economic activity in the County in these alternatives. Figure V-1 indicates the growth pattern of Santa Rosa Centered 478.

Overall Spatial Appearance. These two alternatives are characterized by a very large, dense and spatially extensive Santa Rosa. The physical dimensions of the city are large, even though the densities are high, because of the large Santa Rosa population and the considerable number of jobs located in that city. The other cities in the County have roughly 2 to 3 times their Base Year populations, but are essentially contained within their 1973 boundaries. High density residential areas in these cities are more extensive than in the Base Year, but far less extensive than in the Urban Centered Alternatives. These high density areas are located near the centers of each of the cities. The rural areas of the County and the communities remain essentially the same as in the Base Year.

All the cities generally appear as a series of roughly concentric rings with city-centered commercial and high density residential located near the center, surrounded by medium density residential. A moderate amount of low density residential is located at the outer ring. Interspersed among the low and moderate density residential are several clusters of suburban commerical. Industry is located primarily along the U.S. 101 corridor or near the rail lines. Much of it is within present city limits and the rest is located on the periphery of the residential areas. Vacant land within city limits is minimal. Only land currently used as a public park or for an institution (such as a school, church, or hospital) is left unaffected.

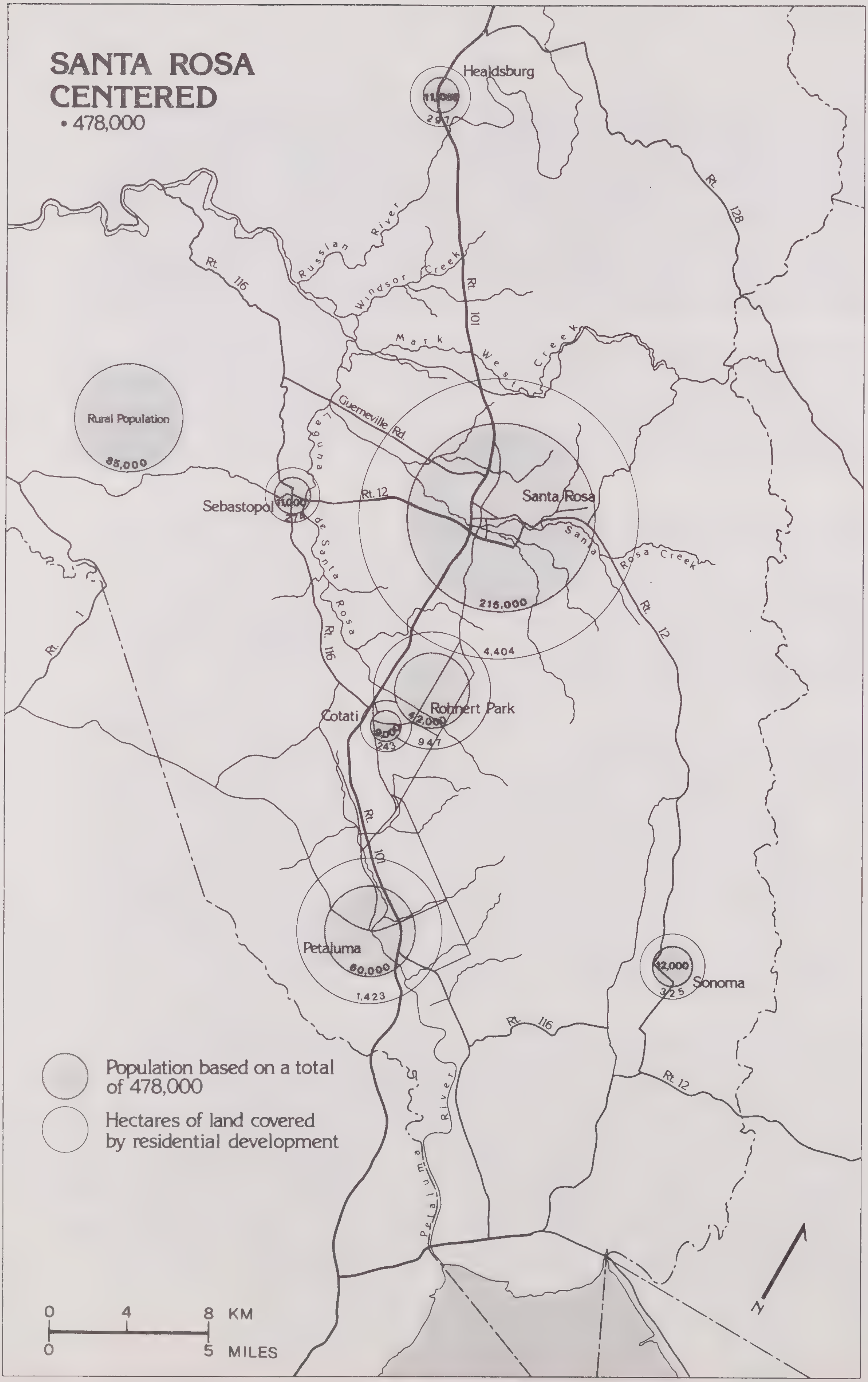

SANTA ROSA
CENTERED
• 478,000
Healdsburg
11,088
297
Rt. 128
Russian River
Rt. 116
Windsor Creek
Rt. 101
Mark West Creek
Rural Population
85,000
Guerneville Rd.
Laguna de Santa Rosa
Sebastopol
11,000
274
Rt. 12
Santa Rosa
Santa Rosa Creek
215,000
4,404
Rt. 12
Rt. 1
Rt. 116
Rohnert Park
Cotati
9,000
243
42,000
947
Rt. 101
Petaluma
60,000
1,423
Sonoma
12,000
325
Rt. 116
Rt. 12
Petaluma River
Population based on a total of 478,000
Hectares of land covered by residential development
0 4 8 KM
0 5 MILES
N

FIG. V–1

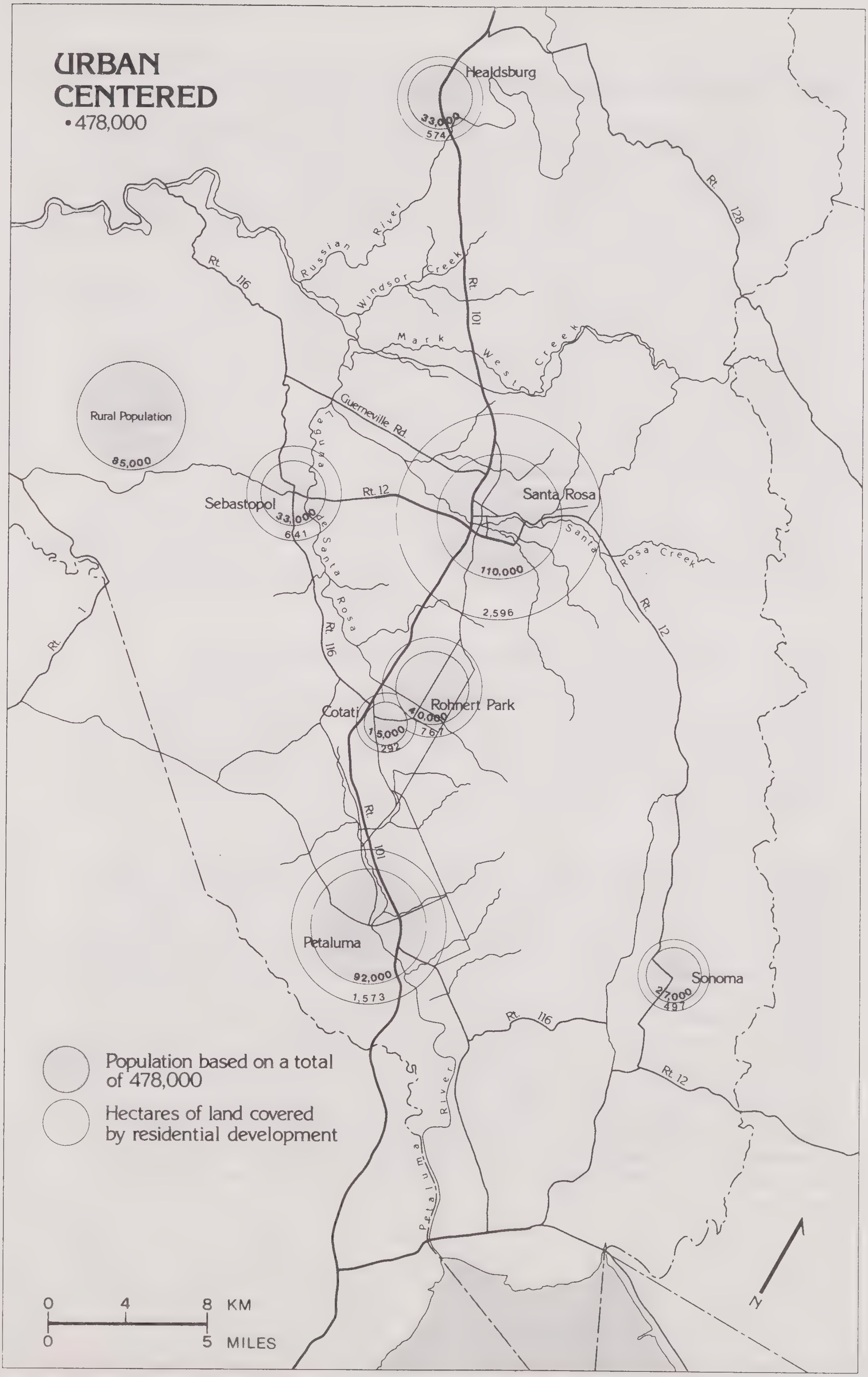

URBAN CENTERED
•478,000
Healdsburg
33,000
574
Rt. 128
Russian River
Windsor Creek
Rt. 116
Rt. 101
Mark West Creek
Guerneville Rd.
Rural Population
85,000
Laguna de Santa Rosa
Sebastopol
33,000
641
Rt. 12
Santa Rosa
110,000
2,596
Santa Rosa Creek
Rt. 12
Rt. 1
Rt. 116
Rohnert Park
40,000
767
Cotati
15,000
292
Rt. 101
Petaluma
92,000
1,573
Sonoma
27,000
497
Rt. 116
Rt. 12
Petaluma River
Population based on a total of 478,000
Hectares of land covered by residential development
0 4 8 KM
0 5 MILES
N

FIG. V–2

Urban Centered (UC) Alternatives: 478,000 and 630,000

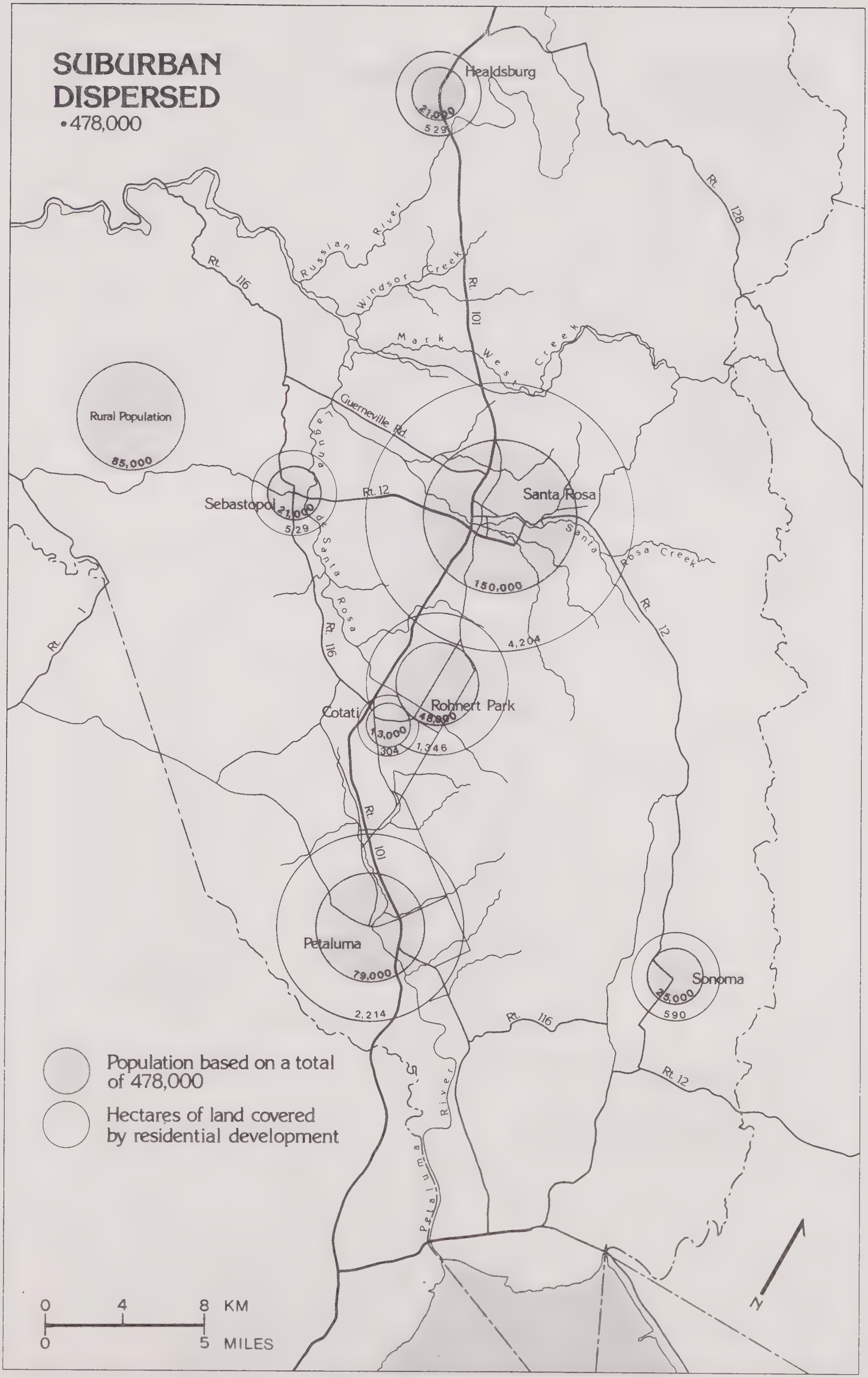
These two alternatives concentrate growth in all of Sonoma County's incorporated cities, while maintaining distinct spatial separations among these urban areas. Employment opportunities grow in each of the cities and Santa Rosa becomes less of a center of economic activity in the County. As in the Santa Rosa Centered growth pattern, development is dense and compact. Figure V-2 displays Urban Centered 478.

Overall Spatial Appearance. In these alternatives, all the cities are large and compact, and the rural portions of the County remain essentially the same as they are now. Cities that were 4,000 in 1973 become cities of 30,000 and 40,000, and Petaluma grows from 30,000 to 92,000 and 126,000, respectively, in UC 478 and 630. Santa Rosa, on the other hand, only doubles in population over the Base Year. The Urban Centered alternatives are differentiated from those of Santa Rosa Centered in that all the cities except Santa Rosa have a much larger and denser core area and require more land for development. Santa Rosa, in contrast, is about half the size. Commercial and industrial locations follow the same assumptions as in the Santa Rosa Centered alternatives, but the amount of land devoted to these uses is much greater in all the cities except Santa Rosa. The rural population remains the same as in the previously discussed alternatives.

Suburban Dispersed (SD) Alternatives: 478,000 and 630,000

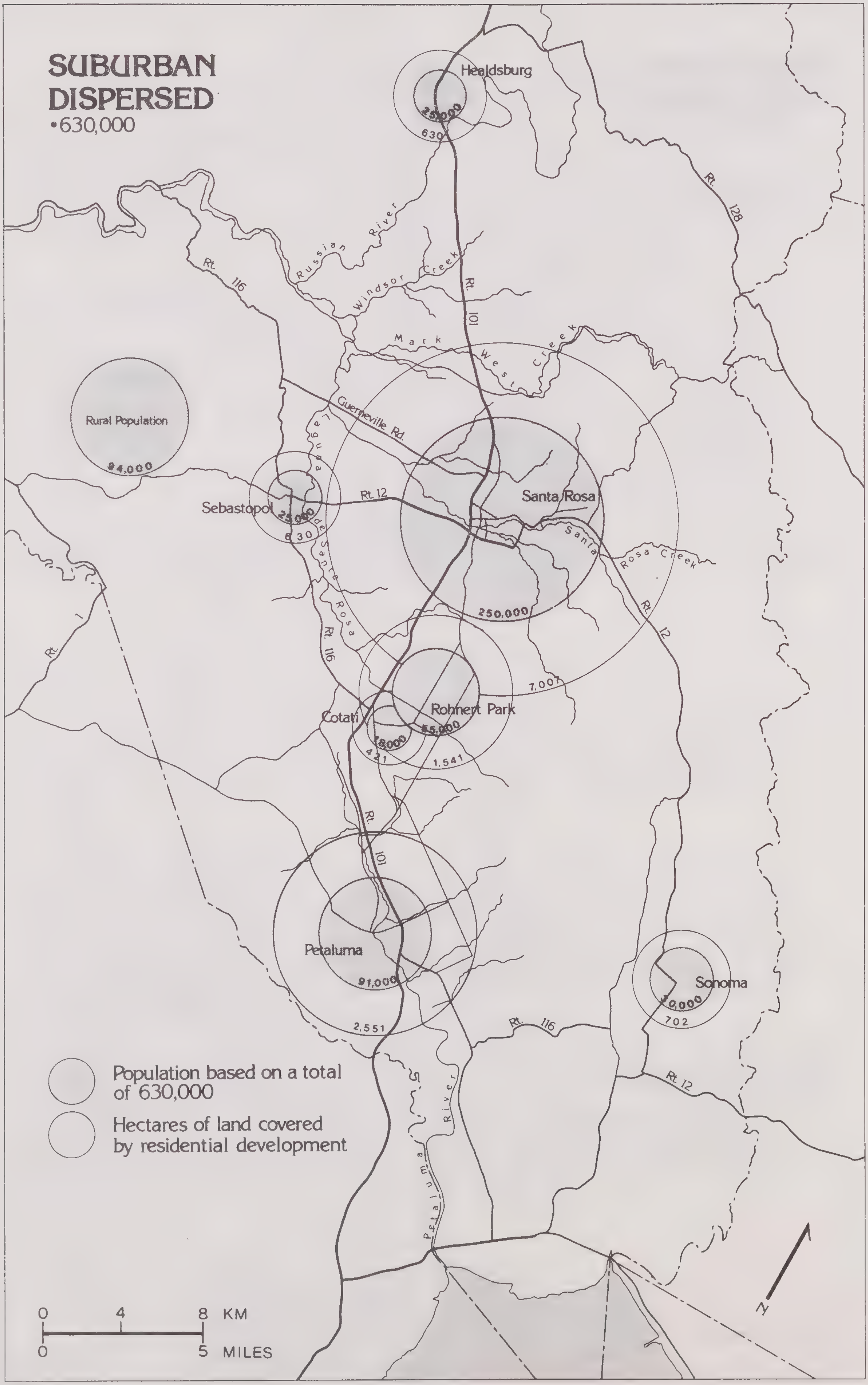
The intent of the Suburban Dispersed alternatives is to create a sprawling, urban fringe-oriented growth pattern where the heaviest development takes place on the periphery of the existing cities, and the predominant housing type is a single-family detached home. Figures V-3 and V-4 illustrate spatial extent of Suburban Dispersed 478 and 630.

Overall Spatial Appearance. These alternatives have, by a large margin, the greatest amount of developed land. For example, Santa Rosa stretches to the floodplain of the Laguna de Santa Rosa on the west and into the Valley of the Moon on the east. By comparison, Santa Rosa in Santa Rosa Centered 630, with a population of 306,000, contains approximately the same residential acreage as the Santa Rosa in Suburban Dispersed 478, with a population of 150,000. Petaluma sprawls outward to the foothills both to the west and to the east. Strips of commercial and apartment house development stretch out along major roads. Commercial development is also placed into large shopping centers and neighborhood shoppping areas scattered throughout the new residential areas. The commercial growth of the existing downtown areas is relatively minor. Industrial development, as in the other alternatives, occurs primarily near the highways and the railroad. The rural areas remain the same as in the alternatives described earlier.



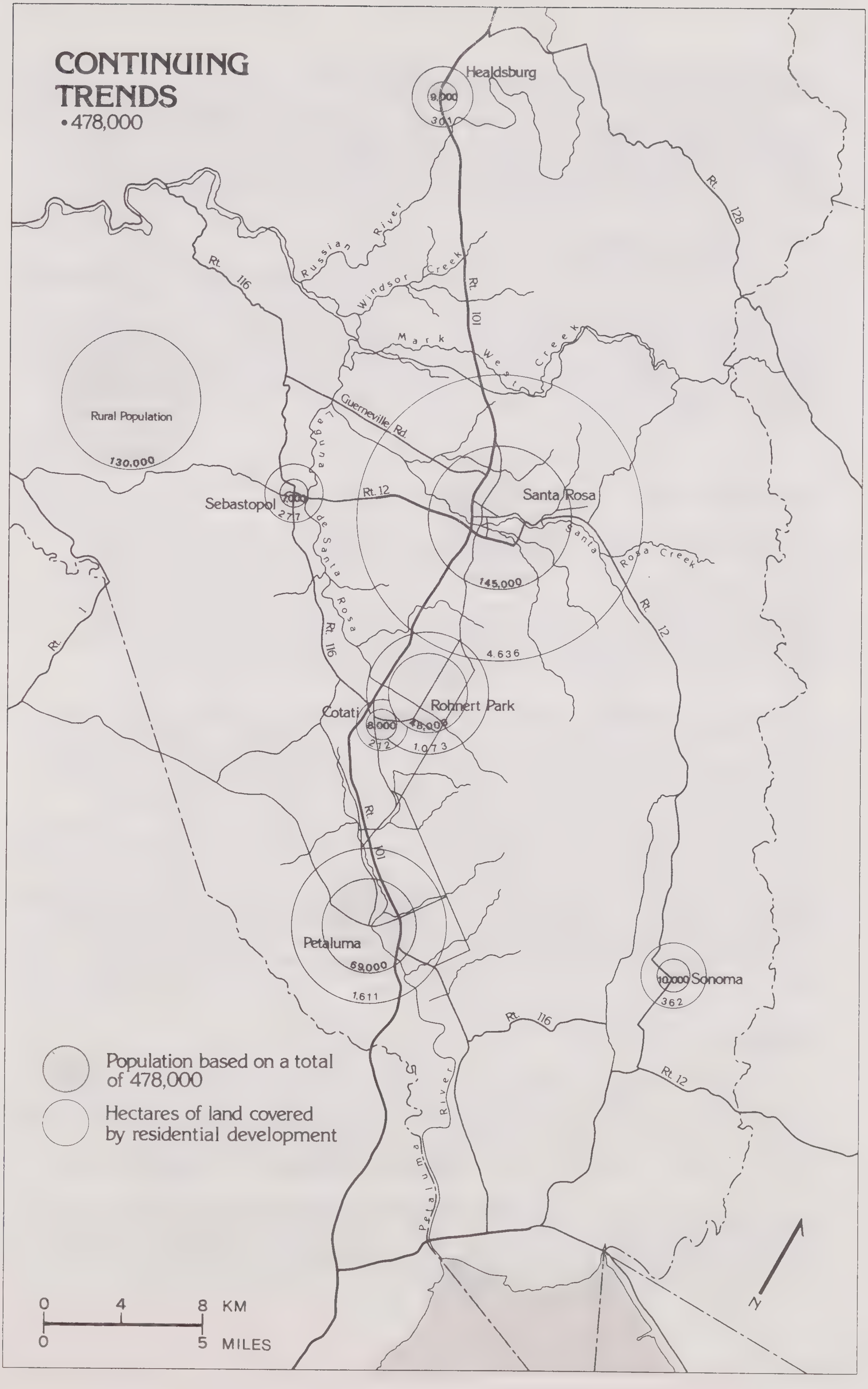
SUBURBAN DISPERSED
•478,000
Healdsburg
21,000
529
Rt. 128
Russian River
Rt. 116
Windsor Creek
Rt. 101
Mark West Creek
Rural Population
85,000
Guerneville Rd.
Laguna de Santa Rosa
Sebastopol
21,000
529
Rt. 12
Santa Rosa
Santa Rosa Creek
150,000
4,204
Rt. 12
Rt. 1
Rt. 116
Rohnert Park
Cotati
48,000
13,000
304
1,346
Rt. 101
Petaluma
79,000
2,214
Sonoma
25,000
590
Rt. 116
Rt. 12
Petaluma River
Population based on a total of 478,000
Hectares of land covered by residential development
0 4 8 KM
0 5 MILES
N

FIG. V–3



SUBURBAN DISPERSED
•630,000
Healdsburg
25,000
630
Rt. 128
Russian River
Windsor Creek
Rt. 116
Rt. 101
Mark West Creek
Rural Population
94,000
Guerneville Rd.
Laguna de Santa Rosa
Sebastopol
25,000
630
Rt. 12
Santa Rosa
Santa Rosa Creek
250,000
7,007
Rt. 1
Rt. 116
Rohnert Park
55,000
1,541
Cotati
18,000
421
Rt. 101
Petaluma
91,000
2,551
Sonoma
30,000
702
Rt. 116
Rt. 12
Petaluma River
Population based on a total of 630,000
Hectares of land covered by residential development
0 4 8 KM
0 5 MILES
N

FIG. V—4



CONTINUING TRENDS
•478,000
Healdsburg
9,000
301
Rt. 128
Russian River
Windsor Creek
Rt. 116
Rt. 101
Mark West Creek
Rural Population
130,000
Guerneville Rd.
Laguna de Santa Rosa
Sebastopol
7,000
277
Rt. 12
Santa Rosa
145,000
4,636
Santa Rosa Creek
Rt. 12
Rt. 1
Rt. 116
Cotati
8,000
212
Rohnert Park
48,000
1,073
Rt. 101
Petaluma
69,000
1,611
Sonoma
10,000
362
Rt. 116
Rt. 12
Petaluma River
Population based on a total of 478,000
Hectares of land covered by residential development
0 4 8 KM
0 5 MILES
N

FIG. V–5

Rural Dispersed (RD) Alternative: 478,000

This land use alternative is designed to demonstrate the effect of developing the rural portions of the county with low density residential developments and "ranchettes" one to ten acre parcels with a house, farm animals and garden or small plot of cultivated land.

Overall Spatial Appearance. In this alternative the Santa Rosa Plain is carpeted with three acre rural residential lots. Development extends to the mountains on both the east and west sides of the Planin and there is virtually no land left untouched within this area. Cities and communities experience only a 25% increase in population and remain essentially the same size as they are now. Commerical and industrial development is similar to that of the Suburban Dispersed 478,000 alternative with new commercial shopping located at the fringes of the cities.

Continuing Trends (CT) Alternatives: 478,000 and 630,000

The Continuing Trends alternatives are developed to show what would happen if the present growth patterns continued to the year 2000. Since Sonoma County Planning Department had already completed growth trend projections for the County at the population levels 478,000 and 630,000, these alternatives essentially were a conversion of the County's projections into a form comparable with the study's other alternatives. Figure V-5 illustrates Continuing Trends 478.

Overall Spatial Appearance. These land use patterns are typified by having a large amount of development along the U.S. 101 corridor with Santa Rosa, Rohnert Park and Petaluma all experiencing considerable growth. Cotati, Rohnert Park and Santa Rosa virtually grow together and Santa Rosa expands northward towards Healdsburg. Residential densities increase only slightly over what presently exists, thereby requiring a continued conversion of present day agricultural land into new urban development. Commercial development expands primarily around its current locations and industrial growth is heavily corridor-oriented. Unlike the other alternatives, existing small unincorporated communities throughout the County grow substantially and the rural areas increase in population by about 50% over the Base Year.

MODELING OF WATER QUALITY

Two separate forms of water quality simulation are conducted in the Sonoma Study. QUAL-II is used to study the impacts of the different land use alternatives on dry weather water quality. A Runoff-Quality model is used to evaluate water quality impacts during periods of storm runoff. Both models are described in detail in Appendix F.

The modeling analysis for dry weather conditions varies only according to the population size being served by the various sewage treatment plants that discharge treated effluent in the study area rivers. As

such, the other growth alternative characteristics of spatial pattern, land use density or land use type are not critical in the analysis. In contrast, wet weather water quality conditions are influenced by all of these characteristics. Consequently, this section of the chapter will concentrate on the surface runoff modeling techniques. (A brief description of QUAL-II will be provided in Chapter VI as part of the explanation of the results from the dry weather water quality analysis.)

Modeling of Surface Runoff Water Quality

Two models, the Urban Runoff and Agricultural Runoff Models, are combined to provide a runoff and quality model. These two models are variants of the EPA's Storm Water Management Model (SWMM). This Runoff-Quality Model predicts the storm water runoff, including its pollutant washoff, for different urban and non-urban land use categories during a selected storm event and routes the runoff from the watershed through major drainage and river channels.

The main steps in predicting surface runoff include:

1) Geographic definition of hydrologic sub-areas in the study area.

2) Physical description of the sub-areas -- land uses, percent imperviousness, soil infiltration characteristics, depression storage, average slope, hydraulic roughness.

3) Description of channel characteristics -- width, depth, slope, length and roughness.

4) Selection of pollutant loadings to wash off with storm water.

5) Selection of appropriate storm conditions for testing.

Geographic Definition of Hydrologic Sub-Areas. Two major basins were chosen to be modeled for water quality -- the Laguna de Santa Rosa and the Petaluma River Basin. (The Valley of the Moon did not receive water modeling attention because the information derived from the other two basins was felt to be sufficient for study purposes.) The watersheds of the main rivers (the Laguna and Petaluma River) are termed "basins" and the watersheds of the major tributaries are termed "watersheds." These watersheds are, in turn, broken down into smaller hydrologic units called "sub-areas."

Sub-areas are defined using the following criteria:

1) areas of homogeneous slope,

2) areas either predominantly developed or undeveloped, and

3) comparable flow path lengths from points along the perimeter of a sub-area to the tributary draining the sub-area.

Each sub-area contains one or more tributaries or parts of tributaries. For modeling purposes, in cases where more than one tributary drains a sub-area, a single tributary is chosen to represent the drainage channel.

After all the watersheds and sub-areas were defined in both basins, their hydrologic boundary lines were translated into 1-km grid cell lines. Thus, all sub-areas were described in terms of grid cells, making them compatible with the land use data system.

Physical Description of the Sub-Areas. The physical description of the various sub-areas provides the key to understanding the impact of urban growth and related land use control measures on water quality. The various land uses, discussed earlier as part of the alternative growth pattern description, are the key variables in the sub-areas.

The land use categories were reviewed for their imperviousness to rain water absorption and thus to greater amounts of storm water runoff. The impervious surface coverage percentages that are used in the study are:

Land Uses	Percent Impervious
Low Density Residential	35
Medium Density Residential	65
High Density Residential	80
Commercial - City Centered (retail/office)	95
Commercial - Suburban	90
Industrial	98
Grazing and Open Space	6
Agriculture - Orchard/Vineyard	6
Agriculture - Truck/Field crops	6
Wetlands	100

The procedures used in determining these impervious percentages were:

1) review of existing zoning codes in Sonoma County for lot coverage requirements,

2) application of professional experience from researching similar areas,

3) review of literature on impervious surface and

4) review of aerial photo maps of Sonoma County.

The surface infiltration rates for soils within Sonoma County were determined using information from the United States Department of Agriculture Soil Conservation Service. The slope, hydraulic roughness, and depression storage of the sub-areas were also determined from soil survey maps or other studies.

Description of Channel Characteristics. Having defined the two major basins in the study area, Laguna de Santa Rosa and Petaluma River, and the runoff characteristics for the sub-areas, the next step is to describe the hydraulic properties of the drainage or stream channels draining the sub-areas. The sub-areas are represented in the model as idealized rectangular areas having uniform groundcover and slope. However, because real catchment areas do not experience uniform overland flow, average values must be assigned to each sub-area.

Actual channel site examinations were necessary in order to determine the specific characteristics of channels represented in the model. Eighty-one stations were chosen for observation in the Laguna and Petaluma Basins. Each station provided a representative cross-sectional area at a portion of a channel. Stations were located at the headwaters, near the middle of channels, and at downstream locations.

Data collected at each station included channel width, depth and slope of the channel banks. Special note was taken of the debris in the channel so that a hydraulic roughness factor could be assigned to each channel.

Selection of Pollutant Loadings. Pollutants in developed areas accumulate in gutters or on other impervious surfaces and are washed off during the next storm. The key variable in the Runoff-Quality Model accounting for the pollution load in urban areas available for washoff is the accumulation of dust and dirt. The daily rates of the buildup of dust and dirt per unit length of curb and gutter vary by land use.

All water quality pollutants are expressed as a function of the accumulation of dust and dirt. They were derived from past studies in other geographical areas and not from a sampling program conducted as part of the Sonoma Study. Time and budget considerations precluded the latter approach. The pollutants considered are total suspended solids, nonsettleable solids, biochemical oxygen demand (BOD), oil and grease, fecal coliforms, total nitrogen, total phosphorus and total heavy metals.

Pollutant loadings for urban land use categories are adopted from WRE's recently completed work in Seattle, Environmental Management for the Metropolitan Area Cedar-Green River Basins (U.S. Army Corps of Engineers, 1974). The original EPA Storm Water Model used pollutant loading rates determined in a separate study in the Chicago area. These rates did not seem applicable for the Seattle area in light of data obtained from additional studies recently performed in the local area. Based on the EPA report titled, Water Pollution Aspects of Street Surface Contaminants, dated November 1972, an average loading factor for total dust and dirt of 0.72 pounds per day per 100 feet of curb was adopted. This rate of 0.72 is less than one half of the average loading used in the original model. Relationships of water quality parameters to total dust and dirt were determined from samples taken in Seattle. Quality data was obtained for a few select storms at the gaging manholes of the calibration areas. The quality data

consisted of the analysis of the manhole grab samples for a total of 28 water quality parameters. The grab samples were taken at a minimum interval of 15 minutes for the duration of the rainfall event.

The loading rates, developed in the Seattle study and used for the Sonoma Study, may be compared to the ratio of BOD, nitrogen, phosphorus, oil and grease and total heavy metals emissions to emission of total suspended solids estimated in the San Francisco Bay Basin Plan. These comparisons are given in the chart.

	Basin Plan (Sonoma County) Parameter/Total Suspended Solids, mg/g	Sonoma Study Rates Parameter/Total Suspended Solids, mg/g		
	URBAN	Residential Light	Residential Heavy	Commercial
BOD/TSS	126	106	212	80
N/TSS	19	22	20.4	14
P/TSS	3.4	3.1	4.3	1.4
Oil and Grease/TSS	71	132	314	67
Total Heavy Metals/TSS	14	6.3	9.1	5.0

Urban land use categories were not presented in detail in the Basin Plan. Consequently, only general comparisons can be made. However, the Basin Plan ratios of mass emissions to total suspended solids appear to fall within the range of loading values used in the Sonoma Study.

The washoff from the non-urban areas is predicted by use of the Universal Soil Loss Equation. The same pollutants used for urban areas are used for non-urban areas. They were determined as a ratio of the anticipated soil erosion washing off the non-urban land uses (e.g. grazing and open, orchard and vineyard agriculture, and truck/field crop agriculture).

Selection of Appropriate Storm Conditions. The selection of a storm event to be used in runoff simulations is important depending on the type of land use impacts or runoff management techniques to be studied. The types of storms that may be of interest include:

1) first significant storm of the winter season
2) "typical" winter storm
3) storm with a 1-year recurrence interval
4) storm with greater than 1-year recurrence interval.

The first event described above will probably produce the greatest pollution during the wet season. The second event should represent "average" wet weather quality. The third and fourth events are of interest mainly from a flood flow design standpoint.

The "typical" winter storm was used for simulation purposes in the study. The intensity of the storm was determined by a review of historical rainfall records in Santa Rosa.

Since there is little historical wet weather water quality data for Sonoma County streams, verification of the water quality portion of the runoff model was not possible. Various storms will produce quite different quality results depending on a number of factors, such as preceding weather conditions, rainfall intensity, and total rainfall.

Because the model is unverified, it was decided to use a single storm event for analytical purposes. The simulations for a single event are useful for comparing the overall water quality impacts of alternate land use configurations and for evaluating the relative accomplishments of certain runoff management techniques. More detailed evaluations of runoff management techniques should consider other storm events and varying antecendent conditions (e.g. number of dry days preceeding the storm).

Relationship of Water Model Variables to Government Policy Making

There are basically four approaches to control pollutants from storm water runoff: 1) preventing contaminants from reaching a ground surface, 2) improving street cleaning or soil practices where contaminants may be present, 3) detaining and treating runoff prior to discharge into the streams and 4) reducing storm runoff through land use controls. The study has used the modeling techniques to assess the effectiveness of these different approaches in the following manner:

1) preventing contaminants from reaching the surface - model runs based on two different frequencies of dust and dirt build-up periods have been made in the study. The use of different build-up periods, ten days and twenty days, simulates the relative importance of requiring and actively enforcing health ordinances whereby certain contaminants are either not used or not permitted to wash off into areas that are part of the storm drainage system, as in the cases of oil and grease from service stations.

2) improving street cleaning or soil practices where contaminants may be present - the use of different frequencies of dust and dirt build-up in the streets can simulate the frequency

of street sweeping. A ten day build-up reflects a ten day sweeping cycle. This approach of varying the build-up rate can be used to determine the optimum pattern and frequency of sweeping.

3) detaining and treating runoff prior to discharge into the streams - one of the model variables can be altered to reflect storm-water detention such as on a slightly depressed parking lot, a catchment basin on a rooftop or a pond in a residential development. Detention devices can be required as part of building regulations or conditions of zoning.

4) reducing storm runoff through land use controls - the arrangement of land uses in the sub-areas, as in the case of the various alternative land development patterns, or the use of measures that result in less impervious surfaces in new developments, can be tested by the model for their effectiveness. Examples of the latter would be requirements for more open space in subdivisions, use of porous pavements for streets and parking lots or use of smaller curb, gutter and road widths in subdivision regulations.

AIR QUALITY MODELING

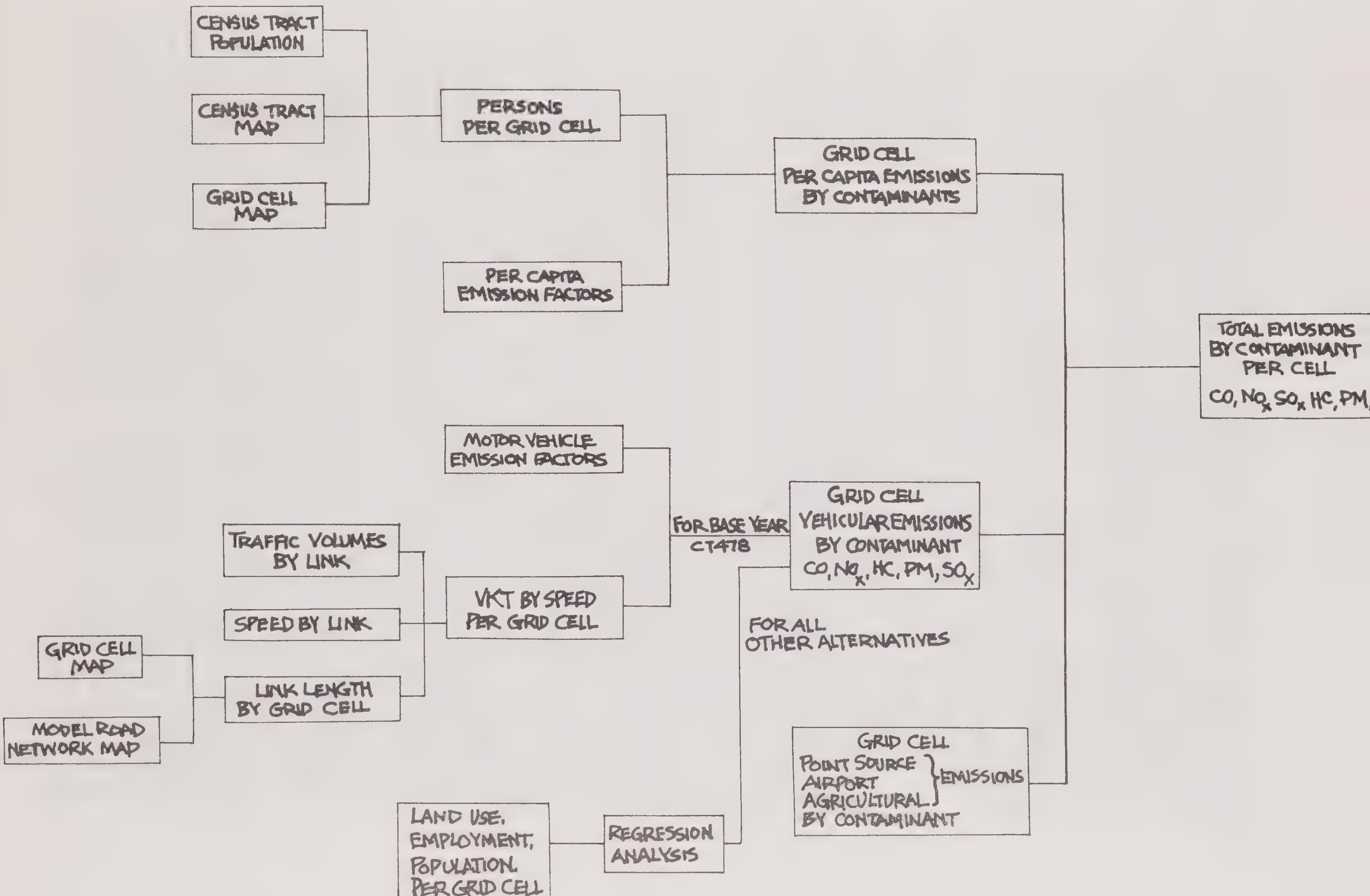
Two separate types of air quality modeling are used in the Sonoma Study. Non-reactive pollutants -- carbon monoxide, total suspended particulates and sulfur dioxide, were simulated by use of a dispersion model based on climatological phenomena. Photochemical oxidant, which is a reactive pollutant, is modeled by a modified proportional roll-back, a technique which assumes that the maximum concentrations of oxidant in an sub-basin (such as the Santa Rosa Plain) are directly related to emissions of non-methane hydrocarbons in that sub-basin as well as emission from other areas in the air basin. Average wind patterns were used to determine the import of non-methane hydrocarobns from outside the sub-basin. Nitrogen dioxide is not analyzed because of the limited modeling techniques available for this pollutant.

The Sonoma County Advanced Planning Division and the Bay Area Air Pollution Control District had agreed to perform air quality analysis of the alternative plans developed in the County General Plan program prior to the inception of this study. The BAAPCD was to provide technical advice and assistance to the County on the preparation of a emission inventory and conduct mathematical modeling to determine pollutant concentrations and violations of air quality standards. The County prepared the alternative plans and directed transportation studies capable of being assessed for their contribution to pollution emissions. Figure V-6 provides a graphical description of how the emissions were compiled.

The Sonoma County/BAAPCD work was delayed with the creation of this study in order to determine if there were any modifications necessary to the data such that they would be easily used for joint air and water quality investigations. In particular, the question of land use

FIGURE 7.6

COMPILATION OF TOTAL EMISSIONS BY GRID CELL



emission factors was explored to determine if appropriate types and amounts of air emissions or water pollutant loadings could be associated with particular land use activities. Review of the literature yielded limited information on this subject, especially for the relatively low population and employment levels that are characteristic of Sonoma County. The air quality analysis then proceeded by preparing an emission inventory and modeling pollutants from three different types of sources: 1) stationary, 2) area and 3) mobile.

Stationary Source Emissions. The Bay Area Air Pollution Control District maintains a detailed inventory of total emissions for each county in its jurisdiction. This inventory provided the basis for calculating the stationary source emissions in the study area.

Estimates of future emissions are made by the BAAPCD for each of its 105 stationary source categories in the Bay Area through projections of demand for products associated with each category and availability of materials such as natural gas and low sulfur fuel oil. Cement patching plants in Petaluma and a food processing plant in Sebastopol are examples of stationary sources in the study area. The emission factors are based on compliance with current BAAPCD regulations. The possibility of significant technological advances in emission control devices or new, more stringent regulations are not reflected in emission estimations.

This projection method is then applied for each grid cell which presently has stationary sources. The year 2000 stationary source projections, which were specifically associated with the Continuing Trends 478,000 alternative, are used for all other land use alternatives. The intent of this method is to keep stationary source emissions constant throughout all alternatives in order that their impacts did not obscure those created by non-stationary sources (e.g., cars, trucks) and population related sources (e.g. home furnaces). It should, therefore, be noted that the use of the Continuing Trends 478 stationary sources in the other land use alternatives may understate the amounts of pollution from those sources. This may be particularly true in Santa Rosa, in the Santa Rosa Centered alternatives, and all of the alternatives at the 630,000 population levels. This problem is expected to be minor due to the limited number of stationary sources presently in the study area.

Area Sources. As explained earlier, the use of land use emission factors was determined inappropriate due to the lack of available information. Therefore, it was decided to distribute area emissions (e.g., emissions from home heating, house painting, neighborhood dry cleaning establishments) proportional to county-wide activities such as population, employment or retail trade or combinations of these activities. Because it was necessary to produce these emissions at a grid cell level, it was decided to use population per grid cell as the means of distributing nonpoint stationary source. A drawback of this technique is that per capita emissions factors from high density structures associated with compact development may well differ from those in low density, single-dwelling developments. In the absence of any empirical data on the subject, a strict proportioning of non-point stationary emissions to population was used.

The per capita emission factors are determined in a straightforward manner:

1) subtracting point source emissions and vehicular emissions from the BAAPCD estimates of 1973 Sonoma County total emissions based upon fuel consumption and economic indices;

2) dividing the difference from the first step by the county population to arrive at the per capita non-point stationary source emission factors for each pollutant.

The same emission factors are used for 1973 (the Base Year) and the year 2000 due to the uncertainties in anticipating control regulations for these sources.

Mobile Emissions. A major section of the Sonoma County General Plan is a Transportation Element. This element was prepared by the Advanced Planning Division and the Department of Public Works, Office of County Roads, with consultation by JHK and Associates. Two of the products of this effort are traffic-loaded road networks based on the existing (1973-Base Year) and Continuing Trends 478,000 land use patterns. The road network loading consists of an average daily traffic (ADT) for most of the roads in the county. The ADT is prepared by traditional transportation modeling based on "productions" and "attractions" of different land uses. Socioeconomic variables in the model include population, employment, land use, income and dwelling units. Transportation variables include route locations, road service levels and speed. Travel is expressed in numbers of trips which the model separates into different travel modes such as vehicle driver, vehicle passenger and transit passenger. External travel, trip patterns that start and/or end outside of the County, are also calculated into the traffic scheme.

The ADT is then translated to a grid cell level by overlaying the grid cell pattern on the road network. This enables the computation of gridded vehicular emissions by use of the table of speed dependent emission factors developed by the BAAPCD, which considers different mixes of cars on the road for 1973 and 2000. (The BAAPCD emission factors are modified versions of the Supplement No. 2 Compilation of Air Pollutant Emission Factors, Second Edition prepared by EPA in September, 1973. Supplement No. 5 is not used in this study because it was issued after the initial air modeling analysis was completed.)

A procedure other than detailed traffic modeling had to be developed to predict vehicular emissions for the other eight land use alternatives (Appendix E). This was necessary because the budget limitations did not permit traffic modeling for each alternative. As a consequence, a regression formula was developed by deriving correlation coefficients between the different emissions and socioeconomic and traffic characteristics per grid cell. The transportation analyses of the Base Year and Continuing Trends 478,000 provided the basis for the regression formula.

This procedure limited the variety of model analyses that could be conducted. The regression formula mathematically explains a series of complex land use and transportation interactions by simple coefficients. In this manner, it obsures the various land use and transportation policy actions that would result in different travel patterns and vehicular emissions estimations. Therefore, it is not possible to test different transportation policy actions. For example, it is impossible to reduce the capacity of a particular road, as a means of testing an air quality strategy of reducing the road network to discourage the use of the car, and be assured that the resultant travel effects are accurately predicted by the formula. Similarly, it is impossible to change the modal split (car vs. mass transit) or the commuter pattern because their impact would be obsured by the formula.

Analysis of Non-Reactive Pollutants

The emissions from the stationary, area and mobile sources are dispersed over the study area by use of a "gaussian plume" model, as described in Appendix C. This model simulates the existing climatological conditions, including wind speeds and directions, at both a regional and local scale. There are three steps in determining the calculation of the concentrations. First, the entire 9-county Bay Area is considered in estimating background concentrations from distant sources. Using wind pattern frequency information and an average wind speed, a factor is developed to represent the contribution to the background pollutant concentrations in the detailed study area from the rest of the 9-county region.

Secondly, the contribution from each grid cell within the study are on the others is computed. This is accomplished by considering all upwind squares as point sources and assuming uniform horizontal diffusion within a certain angle of the wind direction and vertical diffusion as a function of distance.

Thirdly, the local contributions of a grid cell to itself are computed by calculating the average emission density (mass/area/time) and assuming uniform distribution over the grid cell. Then the contribution of each point within a cell is measured on the other points within the same cell, again taking into consideration vertical diffusion and wind direction. The average of the concentrations at all the points within a cell is then assigned as the concentration in the cell.

The annual average concentrations calculated by the above procedure are then analyzed for frequency of violations of air quality standards through the use of the statistical model developed by Dr. Ralph Larsen of EPA. This model converts average concentrations to expected maximum concentrations and expected geometric mean concentrations for various averaging times (e.g. 1 hour, 8-hour). By relating the violations of standards or concentrations of air pollutants to the land use alternatives, it is possible to derive a linkage betwen land use and air quality.

Oxidant Analysis

A rollback approach is used to analyse oxidant concentrations. The analysis is described in detail in Appendix D. Briefly, rollback is based on the premise that the total amount of non-methane hydrocarbons (NMHC) emitted in an air basin is proportional to the maximum oxidant value in that basin. For example, if 100 tons/day of NMHC were emitted in 1973 resulting in a peak hour oxidant value of 16 parts per hundred million (pphm) then a 50 tons/day of NMHC in another year would produce a peak hour of 8 pphm. The above statistical procedures developed by Dr. Larsen are then used to determine how many violations of standards in a year would be expected given the peak hourly oxidant value.

Refinements of the procedure used in the study were breaking down the county into three sub-basins: Santa Rosa, Petaluma, and Sonoma (Valley of the Moon), and considering inter-basin transport. This separation resulted in the analytical ability to distinguish between areas primarily affected by pollutants from other areas versus those originating within the study area.

Relationship of Air Quality Modeling to Government Policy Making

The utility of the air quality modeling in assessing the effectiveness of land use control tools lies in the relationship developed between pollutant emissions and population and employment distribution and density. The degree of population or employment exposure to air contaminants estimated in the different land use alternatives enables the setting of zoning densities, the sizing and structuring of sewage collection and treatment facilities, or the enforcement of other growth directing mechanisms based upon desired air quality objectives. It also assists in decision making of site selection for schools or hospitals that require high air quality.

The second use of the air model to test the impact of government policy is the analysis conducted to determine the effect of partial implementation of vehicular emission control device regulations. This was done by using BAAPCD's average vehicular emission factors for the 1973 vehicle mix, rather than the year 2000 vehicle mix, in assessing the Continuing Trends 478,000 emissions in the year 2000. The impact of the treatment levels created by the different emission devices was dramatic.

Finally, a pilot area analysis was conducted by the Sonoma County Advanced Planning Division to determine the relative effects of differing levels of emission device inspection and enforcement. This examination was aimed at finding what would happen if the latest devices where placed on the car, but later not checked for their adequacy and/or replaced when necessary.

The next chapter will describe the results of the different model simulations.

CHAPTER VI - RESULTS OF MODEL ANALYSIS

The results of the various model analyses provide a number of findings useful for developing environmental management strategies. The water quality analysis emphasizes the influence of watershed characteristics on both dry and wet weather pollution. The air quality analysis emphasizes the impact of both spatial land use patterns and meteorological conditions on the quantity and distribution of air contaminants. The water and air quality modeling analysis, as well as some qualitative findings on related pollution problems, is organized into two sections:

1) water quality analysis
   a) dry weather quality
   b) wet weather quality
   c) groundwater impacts

2) air quality analysis
   a) non-reactive pollutants (e.g., particulates)
   b) reactive pollutant (i.e. photochemical oxidants)

WATER QUALITY ANALYSIS

Development in Sonoma County will impact the quality of both the streams within the study area and the receiving waters outside the study area. Increased population levels will result in a greater demand for water and a corresponding increase in wastewater to be treated and discharged. The discharge of municipal wastewater is of particular concern in the Laguna de Santa Rosa and the Petaluma River during low flow periods when the assimilative capacity of the streams is low because of its seriously impacts on the quality of the Russian River and the San Pablo Bay. Urbanization impacts water quality during wet weather periods primarily through increased washoff of pollutants which accumulate in urbanized areas. The analysis also indicates that the impact of development in the county on groundwater resources will be the reduction of natural recharge of groundwater basins and degradation of groundwater quality resulting from the use of septic tanks in rural and low density residential areas.

This section of the report presents the results and analysis of the impacts of the ten alternative urban growth patterns on water quality in the Laguna and Petaluma Basins. Water quality impacts that were not modeled are also briefly discussed. To evaluate the effects of the different growth patterns on the quality of streams within these basins, two separate mathematical models were used: QUAL-II for studying the impacts during low flow periods and a Runoff-Quality Model for evaluating water quality impacts during periods of storm runoff. These models are described in Chapter Five and in Appendix F. Also described in Appendix F are the key model variables unique to

Sonoma County, how they were developed and a description of the work necessary to calibrate the models for use on the Sonoma County water sheds and streams.

The Sonoma Creek watershed is also a part of the study area, but there were insufficient funds to permit modeling of this watershed and stream network. However, some of the conclusions reached in the analysis of model results for the Laguna and Petaluma Basins can be extended to the Sonoma Creek watershed.

Impacts of Development on Dry Weather Quality

The stream quality model QUAL-II was applied to the Laguna de Santa Rosa and the lower reaches of its major tributaries including Santa Rosa Creek, Mark West Creek, and Windsor Creek. In the Petaluma Basin, QUAL-II was applied to the Petaluma River from one kilometer upstream of the confluence of Lichau Creek and the river to 29.5 kilometers downstream.

Simulations of water quality for low flow conditions were made in both the Laguna and Petaluma Basins for Base Year (1973) conditions and most of the land use alternatives. (Some alternatives were not studied because their findings would have been essentially the same due to similar population levels being served by the sewage treatment plants.) The greatest impact of development on low flow quality in both basins is caused by the discharge of treated wastewater from municipal sewage treatment plants. The loads on these plants are a function of the populations served by the sanitary districts. Consequently, the population distributions for the Base Year and each alternative are allocated to the sanitary districts under present and future conditions of treatment plant configurations to arrive at the magnitude and location of treated discharges. Under future conditions, the treatment plant configuration is the same for all land use patterns.

Laguna Basin

In 1973, there were three sewage treatment plant discharges to the Laguna de Santa Rosa and two discharges to Santa Rosa Creek. These discharges and the QUAL-II stream network are shown schematically on Figure VI-1. (The diagram should be read from the top to the bottom of the page for the directional flow of the various tributaries to the Laguna de Santa Rosa, which in turn drains into the Russian River. The diagram is drawn to indicate how the simulation model receives information for each section or "element" of the tributaries.) According to the North Coastal Water Quality Control Plan, a consolidated treatment plant at the existing Laguna STP location will serve most of Santa Rosa, Rohnert Park, Cotati, and Sebastopol, thereby eliminating the Sebastopol and Rohnert Park-Cotati plants. The College Avenue plant will remain in service but it will be limited to a capacity of 220 liters/second (l/sec) (5 mgd). Under future conditions, with the exception of Oakmont, College Avenue will treat up to 220 l/sec of municipal waste flow and the consolidated Laguna plant will treat all the remaining wastewater originating in the Santa Rosa area.

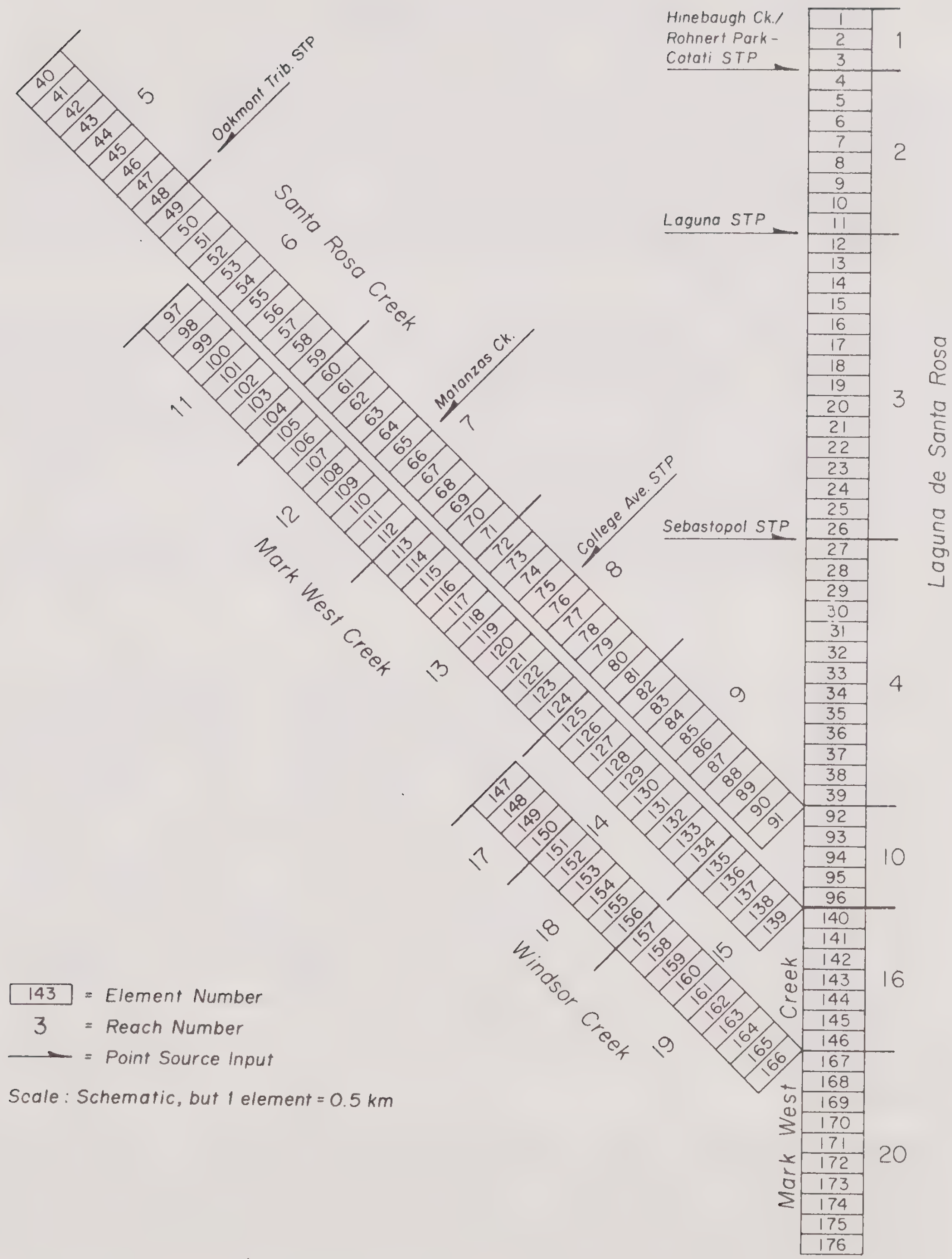


FIG. VI-1

LAGUNA DE SANTA ROSA AND TRIBUTARIES

QUAL-II STREAM NETWORK

The effluent was assumed to be discharged as follows under all alternatives in accordance with the Basin Plan proposals:

Oakmont	- treated and discharged to Santa Rosa Creek
College Ave.	- treated and land disposal
Laguna	- treated and discharged to Laguna de Santa Rosa

Treated effluent at the consolidated Laguna plant may be discharged to land during summer months in the future similar to the current disposal of effluent from the College Avenue plant. Discharges to the Laguna de Santa Rosa may be allowed only during wet weather when the Laguna has a high assimilative capacity. However, for purposes of this study the entire Laguna plant effluent was assumed to be discharged to the Laguna de Santa Rosa.

Wastewater Flows and Characteristics. For the Base Year simulation, the quality of treated effluent was set to that observed in September 1973 at each of the operating treatment plants. Under future conditions the effluent quality was set at or better than the quality defined by the EPA as secondary treated effluent. Table VI-1 shows the concentrations of key constituents used to characterize the quality of effluent discharge to Santa Rosa Creek and the Laguna de Santa Rosa. Flows at each treatment plant were estimated by multiplying the population served by the historic per capita water use for that area, varying by city from 454 liters (120 gallons) to 303 liters (80 gallons) per day.

The EPA definition of secondary effluent calls for BOD concentrations not to exceed 30 mg/1. At the population levels envisioned for several of the growth alternatives BOD concentration of 30 mg/1 depressed dissolved oxygen concentrations to zero in the Laguna de Santa Rosa. Consequently, advanced treatment was assumed in terms of BOD removal at the Laguna plant for most of the alternatives. The effluent BOD concentration at the Laguna plant was set at 30 mg/1 for the Rural Dispersed alternative, 7.5 mg/1 for the Continuing Trends, and at 5.0 mg/1 for all remaining alternatives. Even with reduced BOD concentrations, dissolved oxygen levels were still depressed in the preliminary simulations. In order to maintain some dissolved oxygen in the Laguna de Santa Rosa, it was necessary to reduce ammonia concentrations at the higher STP discharge rates. Table VI-1 shows NH_3 concentrations ranging from 5.0 mg/1 at the Laguna plant for the land use alternatives resulting in high discharge rates to 20.0 mg/1 in the base year.

Simulation Results. Figure VI-2 shows dissolved oxygen concentrations along the Laguna de Santa Rosa for Base Year conditions and for four of the land use alternatives, each at a County population of 478,000. There is a pronounced DO sag downstream from the Laguna plant for 1973 conditions and the Rural Dispersed and Continuing Trends alternatives. Another smaller sag in the Base Year simulation is noticeable downstream from the confluence of Santa Rosa Creek and the Laguna de Santa Rosa. This sag is caused by the discharge to Santa Rosa Creek in 1973

TABLE VI-1

EFFLUENT FLOWS AND QUALITIES USED IN QUAL-II SIMULATIONS

Land Use Alternative	Flow (l/sec)	Constituent BOD (mg/l)	NH_3 (mg/l)	NO_3 (mg/l)	PO_4 (mg/l)
Base Year (1973)					
Oakmont	8	24.0	20.0	25.0	20.0
College Avenue	280	24.0	0.5	25.0	20.0
Rohnert Park-Cotati	39	60.0	20.0	25.0	20.0
Sebastopol	16	26.8	20.0	25.0	20.0
Laguna	80	5.6	20.0	25.0	20.0
Continuing Trends					
Oakmont (478)	16	30.0	20.0	25.0	20.0
Laguna (478)	770	7.5	13.8	25.0	20.0
Santa Rosa Centered					
Oakmont (478)	24	30.0	20.0	25.0	20.0
Oakmont (630)	34	30.0	20.0	25.0	20.0
Laguna (478)	1130	5.0	5.0	25.0	20.0
Laguna (630)	1640	5.0	5.0	25.0	20.0
Urban Centered					
Oakmont (478)	12	30.0	20.0	25.0	20.0
Oakmont (630)	17	30.0	20.0	25.0	20.0
Laguna (478)	620	5.0	5.0	25.0	20.0
Laguna (630)	1020	5.0	5.0	25.0	20.0
Rural Dispersed					
Oakmont (478)	25	30.0	20.0	25.0	20.0
Laguna (478)	200	30.0	13.8	25.0	20.0

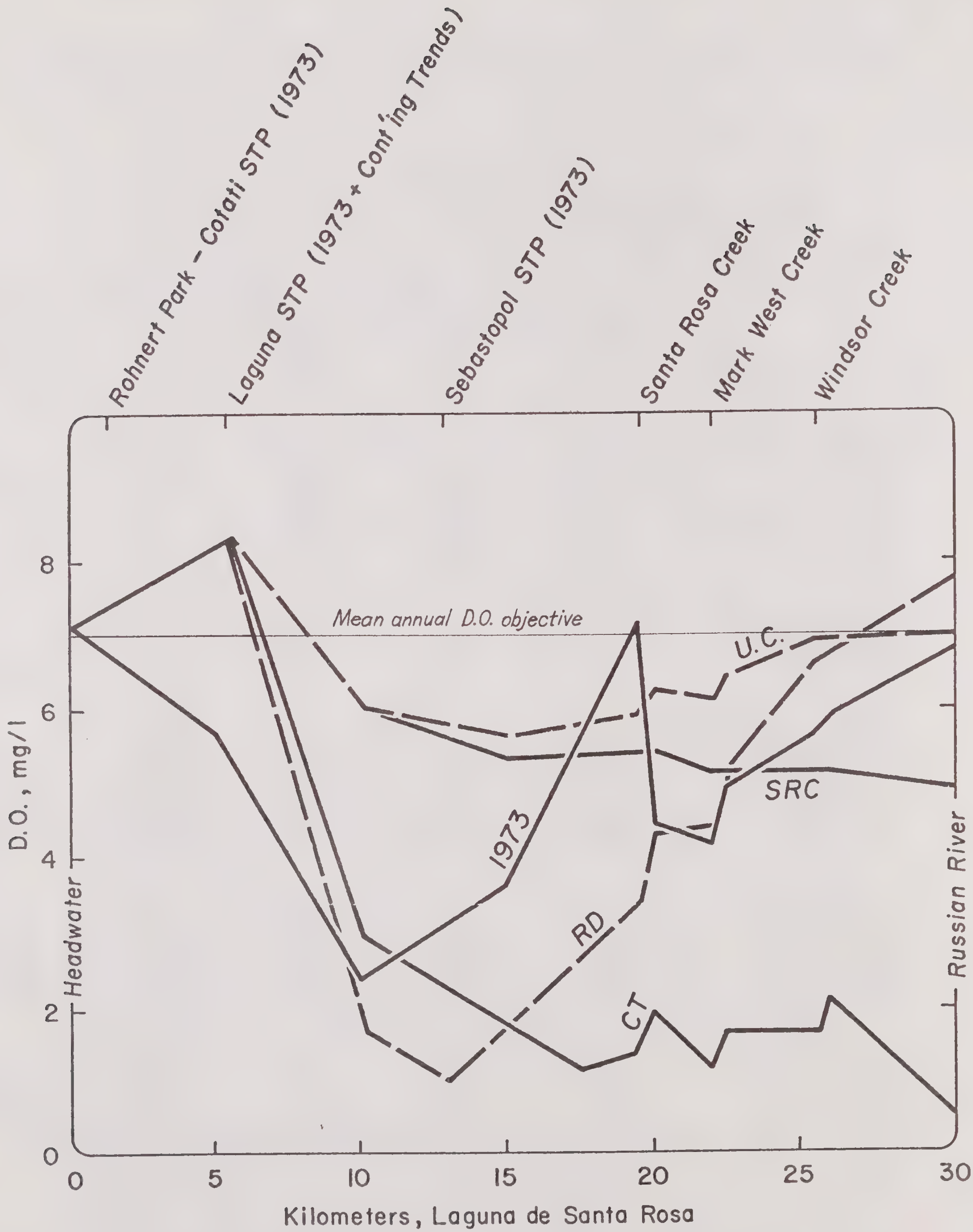


FIG. VI-2
LAGUNA DE SANTA ROSA
DISSOLVED OXYGEN PROFILE
(478,000 population level)

from the College Avenue plant. Dissolved oxygen under the Continuing Trends alternative never recovers from the sag whereas, under the Base Year, Rural Dispersed, Santa Rosa Centered and Urban Centered alternatives, dissolved oxygen concentrations do recover. The reason for this appears to be the NH_3 concentration of 13.8 mg/1 at the high discharge rate of 770 liters/sec. From a fish habitat point of view, the DO levels shown in Figure VI-2 are unsatisfactory for 1973 conditions and the Rural Dispersed and Continuing Trends alternatives.

The North Coastal Basin Water Quality Control Plan shows a minimum DO mean annual objective of 7.0 mg/1 for the Laguna de Santa Rosa. Generally, DO levels below 5.0 mg/1 are not sufficient to support healthy populations of most species of warm water game fish. The Santa Rosa Centered and Urban Centered DO levels, while below the 7.0 mg/1 minimum, appear to be satisfactory for maintaining a fishery in the Laguna. If tertiary treatment (effluent BOD of 5.0 mg/1) were applied to the waste flows at the Laguna treatment plant in both the Rural Dispersed and Continuing Trends alternatives, dissolved oxygen concentrations in the Laguna would be very similar to those shown in Figure VI-2 for the Urban Centered and Santa Rosa Centered alternatives. The main point to be made here is that tertiary treatment would be required at the Laguna plant by <u>all</u> alternatives if the effluent is to be discharged to the Laguna de Santa Rosa during summer months and if the DO objective is to be satisfied.

The quality of water discharged to the Russian River from the Laguna de Santa Rosa is of concern from the standpoint of its impact on the Russian River's important recreation and fishery uses. Table VI-2 shows the quantity and quality of water discharged to the Russian River for Base Year conditions and the land use alternatives shown in Figure VI-2.

TABLE VI-2

QUANTITY AND QUALITY OF LOW FLOW DISCHARGES FROM LAGUNA TO RUSSIAN RIVER (478,000 population level)

Land Use Alternatives	Flow (m^3/sec)	DO (mg/1)	BOD (mg/1)	NH_3-N (mg/1)	NO_2-N (mg/1)	NO_3-N (mg/1)	PO_4-P (mg/1)
Base Year	0.88	6.86	3.32	1.90	0.45	14.87	10.25
Continuning Trends	1.21	0.60	1.49	4.58	1.11	19.98	12.94
Santa Rosa Centered	1.58	5.03	1.32	2.22	0.52	19.75	14.58
Urban Centered	1.06	7.08	0.91	1.71	0.41	16.49	11.93
Rural Dispersed	0.65	7.78	1.88	2.27	0.55	11.54	6.89

All land use patterns in Table VI-2 show high nutrient concentrations. Early in the Basin Planning Program, preliminary nutrient objectives were established for the Russian River. These preliminary objectives were 2.0 mg/1 nitrate and 0.4 mg/1 phosphate. In the summer months the flow of the Russian River at its confluence with Laguna de Santa Rosa may be as low as 3.5 m^3/sec. Obviously, flows from the Laguna on the order of those shown in Table VI-2 would result in nutrient concentrations well above the old objectives for the Russian River. Consequently, nutrient removal is indicated at the Laguna treatment plant to produce a high quality flow in the Laguna that will come close to meeting the quality of the Russian River. It should also be pointed out that while the BOD removal down to 5.0 mg/1 was sufficient to achieve minimum acceptable steady state concentrations of DO in the Laguna, the nutrient load would undoubtedly result in biostimulation within the Laguna itself. The Basin Plan (1) contains an objective stating that waters shall not contain biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses.

A simulation, using the Santa Rosa Centered 478 alternative, was made assuming a very high level of treatment at the Laguna plant. The quality of the effluent was:

BOD - 1.0 mg/1
NH_3 - 1.0 mg/1
NO_2 - 0.0 mg/1
NO_3 - 1.0 mg/1
PO_4 - 0.05 mg/1

The BOD concentration of 1.0 mg/1 maybe a little lower than that which is achieveable with current treatment technology. The design standards for the future Santa Rosa STP suggests 3.0 mg/1 BOD as a median level of performance.

The resultant quality of the Laguna at its confluence with the Russian River was as follows:

DO (mg/1)	BOD (mg/1)	NH_3-N (mg/1)	NO_3-N (mg/1)	PO_4-P (mg/1)
7.29	0.09	0.25	0.05	0.09

This quality compared to the preliminary objectives for the Russian River suggest that tertiary treatment, <u>including nutrient removal</u>, at a consolidated Laguna treatment plant would be required for the increased population levels.

<u>Petaluma Basin</u>

Under Base Year conditions, the Petaluma municipal sewage treatment flows were discharged to the Petaluma River near the City of Petaluma. A new plant was built after 1973 and is presently discharging to the Petaluma River about 4-1/2 kilometers downstream from the location of

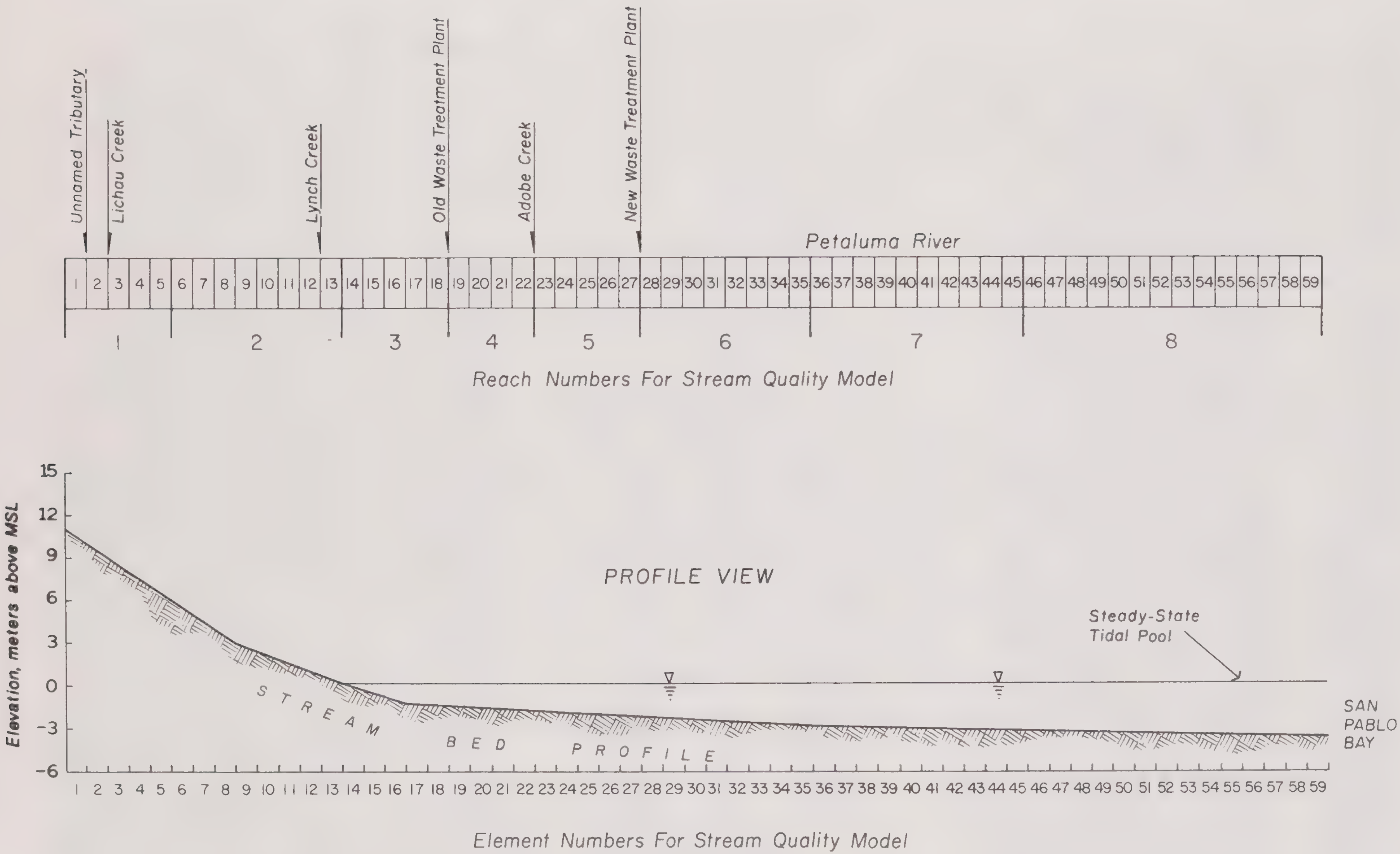


FIG. VI-3

PETALUMA RIVER

QUAL-II STREAM NETWORK

the old plant. The new plant is designed for secondary process with a discharge permit attached requiring higher specified treatment for BOD and suspended solids. These discharges and the Petaluma River QUAL-II network are shown in Figure VI-3.

Wastewater Flows and Characteristics. For the Base Year simulation, the quality of treated effluent was set to that observed in September 1973 at the old plant. Under future conditions, the effluent quality for the alternative growth patterns that were simulated was controlled by the mass emission limitations established by the Regional Water Quality Control Board. This was accomplished by estimating the flow rate associated with the population to be served in each alternative and calculating the concentration of the effluent necessary to stay within the maximum emissions allowed by the Board for BOD, suspended solids and coliforms. Table VI-3 shows the concentrations of key constituents used to characterize the quality of effluent discharges to the Petaluma River.

TABLE VI-3

EFFLUENT FLOWS AND QUALITIES USED IN QUAL-II SIMULATIONS

Land Use Alternatives	Flow (l/sec)	Constituents BOD (mg/l)	NH_3 (mg/l)	NO_3 (mg/l)	PO_4 (mg/l)
Base Year	120	17.0	22.0	8.0	20.0
Continuing Trends (478)	300	5.0	22.0	8.0	20.0
Urban Centered (478)	400	4.2	22.0	8.0	20.0
Urban Centered (630)	550	3.0	22.0	8.0	20.0

The alternatives shown in Table 3 result in the full range of populations that may be served by the new Petaluma treatment plant. The quality of the Petaluma River resulting from intermediate population levels associated with those alternatives which were not simulated may be interpolated from the results of the simulations.

Simulation Results. Figure VI-4 shows the dissolved oxygen concentrations along the Petaluma River for Base Year conditions and for the land use alternatives. The DO sag is caused by the discharges from the old plant in the Base Year case and by Petaluma's new plant in the new land use patterns. The sag increases as the flow rate increases, with the Urban Centered alternative resulting in the greatest discharge to the Petaluma River. Interestingly, Figure VI-4 shows the low point of the sag upstream from the location of the new plant. The Petaluma River is influenced by tidal fluctuations and an upstream salinity gradient from San Pablo Bay. Dispersion caused by the salinity gradients and tidal fluctuation appears to move a significant portion of the BOD and ammonia discharged by the treatment plant upstream.

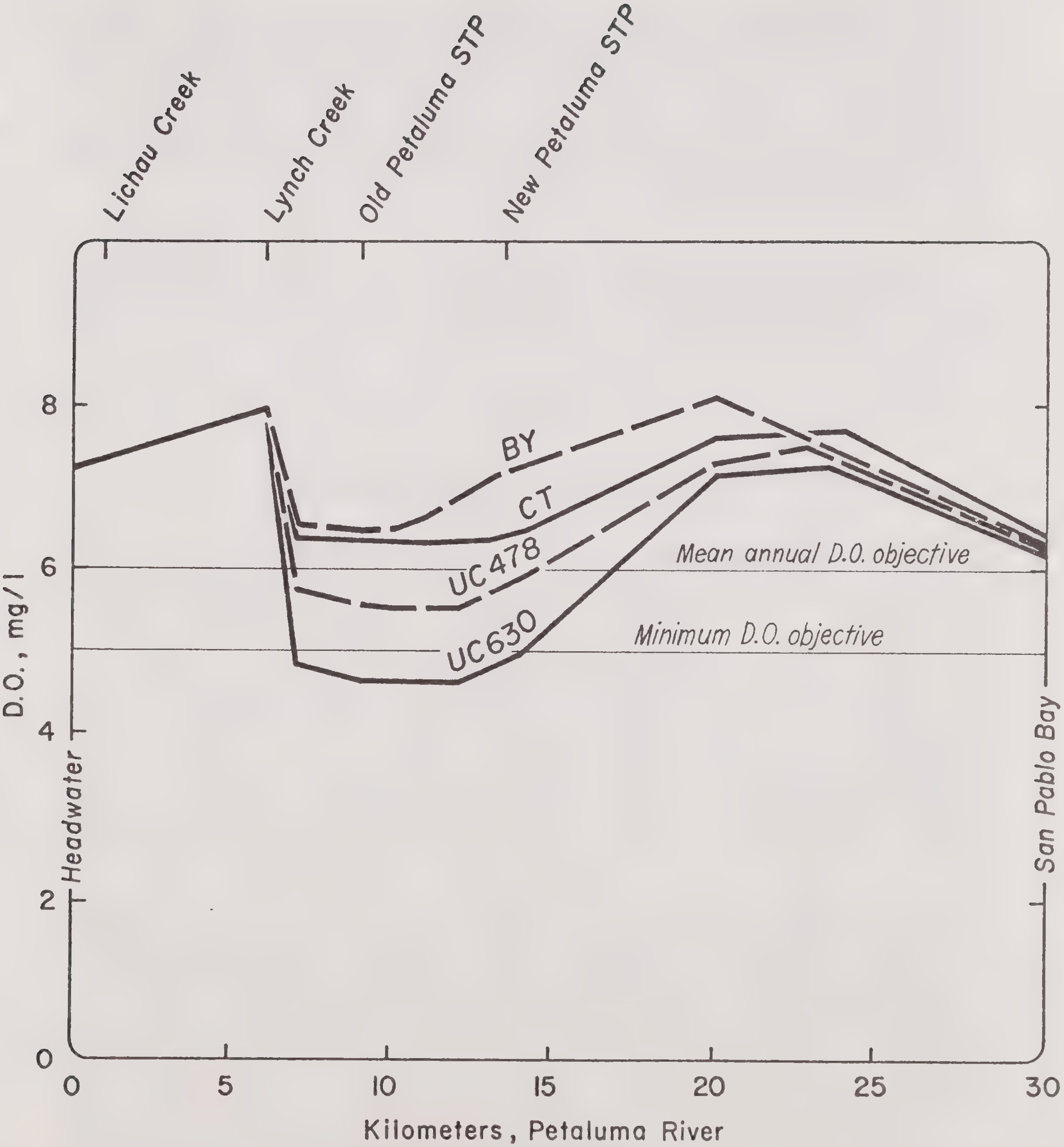


FIG. VI-4
PETALUMA RIVER
DISSOLVED OXYGEN PROFILE

The steady state low flow condition in the Petaluma River, as predicted by the QUAL-II simulations, results in the DO sag near or even upstream from the discharge locations. The differences in concentrations of DO among the land use alternatives or population levels are most reflective of ammonia demands, because the BOD mass emission rates were nearly constant, as constrained by discharge limitations.

The San Francisco Bay Basin Plan states that dissolved oxygen concentrations in Petaluma River shall not be less than 6.0 mg/1 on a mean annual basis and never below 5.0 mg/1. Both Urban Centered alternatives result in DO concentrations below the mean annual requirement, implying that mass emissions from the Petaluma plant may have to be further restricted at population levels equal to or greater than those assumed for Urban Centered 478 or alternatively, the population in the basin should be restricted.

The quality of water discharged to San Pablo Bay is reflected in the values shown in Table VI-4. These values are reflective primarily of the tailwater (San Pablo Bay) concentrations used in all simulations, rather than differences in waste discharge conditions.

TABLE VI-4

QUANTITY AND QUALITY OF LOW FLOW DISCHARGES FROM PETALUMA RIVER TO SAN PABLO BAY

Land Use Alternatives	Flow (m^3/sec)	DO (mg/1)	BOD (mg/1)	NH_3-N (mg/1)	NO_2-N (mg/1)	NO_3-N (mg/1)	PO_4-P (mg/1)
Base Year	0.30	6.47	0.17	0.13	0.03	0.26	0.14
Continuing Trends (478)	0.48	6.46	0.17	0.13	0.03	0.30	0.17
Urban Centered (478)	0.58	6.45	0.17	0.13	0.03	0.32	0.18
Urban Centered (630)	0.73	6.44	0.17	0.13	0.03	0.35	0.20

There is almost no difference between the alternatives in the quality of water discharged to San Pablo Bay. It is not likely that discharges to San Pablo Bay with the quality shown in Table VI-4 would cause a degradation of the Bay with respect to oxygen depletion or biostimulation.

Impacts of Development on Wet Weather Quality

Two models, the Urban Runoff and Agricultural Runoff Models, were combined to provide a runoff and quality model used on the Sonoma County study. This Runoff-Quality Model predicts the runoff and

pollutant washoff from seven categories of urban land uses and three categories of nonurban uses for any selected storm event and it routes the runoff and pollutant washoff from the watershed through major channels, providing a time history of channel flows and qualities for the duration of the storm.

To facilitate preparation of the data needed for the Runoff-Quality Model, a data preprocessor was developed to create watershed characteristics from from land use information. The type of information developed by the preprocessor by subarea is as follows:

1. Percentage of subarea devoted to each land use category
2. Percentage of subarea with impervious surface
3. Maximum and minimum infiltration rates by subarea

The percentage of each grid cell devoted to specific categories of land use was provided for each land use alternative. The Runoff-Quality Model is set up on a subarea basis with each subarea containing several one kilometer grid cells. Consequently, it is necessary to aggregate the land use information and this is done by the preprocessor. A primary use of the land use information by the model pertains to determining the type and rate of buildup of pollutants on urban areas, and the soil loss (erosion) potential in nonurban areas.

As indicated in the Chapter V description of the Runoff-Quality Model, it was next necessary to determine other key variables such as 1) imprevious area percentages per land use, 2) soils and their infiltration rates, 3) watershed characteristics (length, width, slope and roughness), 4) typical storm characteristics, and 5) pollutant loads for both urban and non-urban areas.

For purposes of comparing the impacts of the land use alternatives on wet weather quality, a typical winter storm was used in the model. Historical precipitation in Santa Rosa was reviewed and on the basis of precipitation in 1966 and a "typical" year insofar as total annual rainfall and monthly distribution, a typical winter storm was developed and used in the wet weather simulations. In those portions of the Laguna and Petaluma watersheds with mean annual rainfall of 76.2 cm (30 in), the winter storm produced 2.5 cm of precipitation over a 4-hour period. Five hyetographs were prepared based on mean annual rainfall and the appropriate hyetograph was assigned to each subarea.

Pollutant washoff was computed using the Universal Soil Loss Equation in nonurban areas. In the urban areas, pollutants were assumed to accumulate at specified daily rates. The amount of pollutant load on urban areas available for washoff was directly proportional to the number of dry days preceeding the storm. In the simulations, 20 dry days were assumed to preceed the typical winter storm. Eight types of water pollutants were modeled, including total suspended solids, nonsettleable solids, BOD, grease and oil, fecal coliforms, total nitrogen, total phosphorus and total heavy metals.

In addition to the simulations using the typical winter storm for each growth alternative, other simulations were made. Certain measures have been mentioned in the literature which are concerned with reducing pollutant washoff. Included are such measures as frequent street sweeping, the requirement of on-site detention storage to capture a portion of the runoff washoff load and the requirement of less impervious area per development to reduce runoff. Simulations representing these measures were made for the Santa Rosa Centered 478 alternative.

Since the pollutant load in urban areas available for washoff is a function of the number of dry days preceeding a storm and washoff from nonurban areas is not affected by this, care must be taken in making judgments about the significance of the contribution of pollutant loads from urban areas versus nonurban areas. For a given rainfall event, the washoff from urban areas could be far greater than that from nonurban areas when a long dry period preceeds the storm. For the same event with no dry period, the washoff from the nonurban areas, which would be the same as in the first case, could be far greater than that from the urban areas. More detailed evaluations of runoff management techniques must consider different storms and various antecedent conditions if the overall effectiveness toward pollution abatement of the techniques is to be evaluated.

Laguna Basin

Figure VI-5 provides a guide map to both the Laguna and Petaluma Basins. The Laguna Basin covers 668 square kilometers and is represented in the Runoff-Quality Model by four watersheds and 45 channels. The watersheds are further broken down into subareas. In the Windsor Creek, Mark West Creek, Santa Rosa Creek, and Laguna de Santa Rosa watersheds there are 6, 7, 12 and 15 subareas, respectively, with an average area of 16.7 sq. km. Figure VI-6 shows the subareas and channels represented in the model for the Laguna Basin.

As mentioned previously, eight types of pollutants were modeled for each of ten land use patterns. However, for purposes of comparing the relative impacts of the different patterns on water quality, only total suspended solids parameters is used. In rural areas, the model computes the total suspended solids washed off the watershed by the Universal Soil Loss Equation. The other seven pollutants are computed as a constant fraction of total suspended solids but are variable by land use type. In urban areas all pollutants are computed as fractions of total dust and dirt. Consequently, the amount of total suspended solids washed off the watershed or the concentration of total suspended solids in the channel are good indicators of the relative pollution load.

Table VI-5 shows the peak concentrations of total suspended solids for each channel in the Laguna Basin and the total suspended solids washed off the subareas tributary to the channels. Washoff from the subarea is presented as urban and nonurban washoff. The urban load is the sum of all residential, commercial and industrial uses and the nonurban load is the sum of all open and agricultural uses. Figure VI-7 indicates stream quality in various channels as a result of the different patterns.

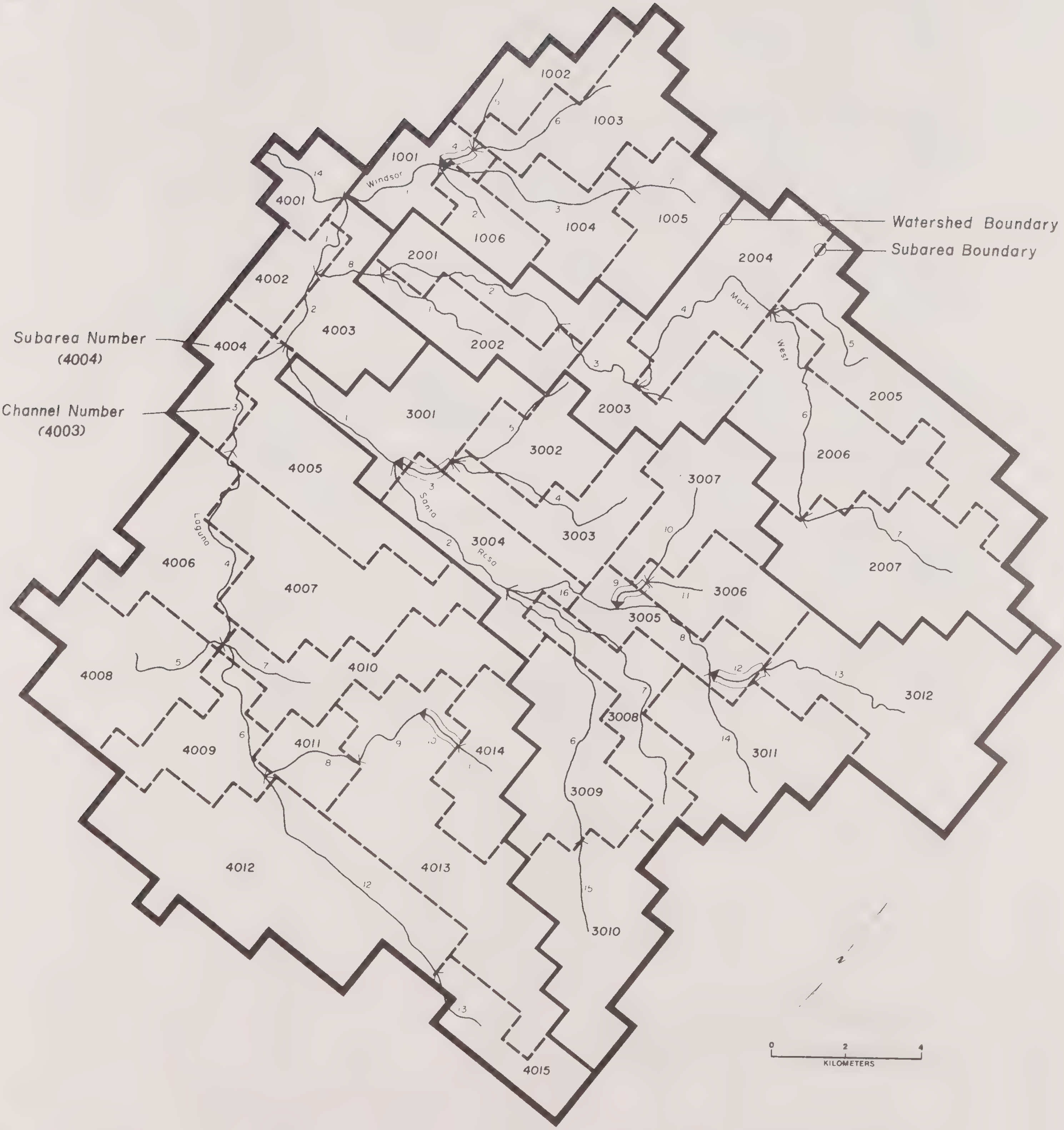


FIG.VI-6

LAGUNA BASIN

SUBAREAS AND CHANNELS

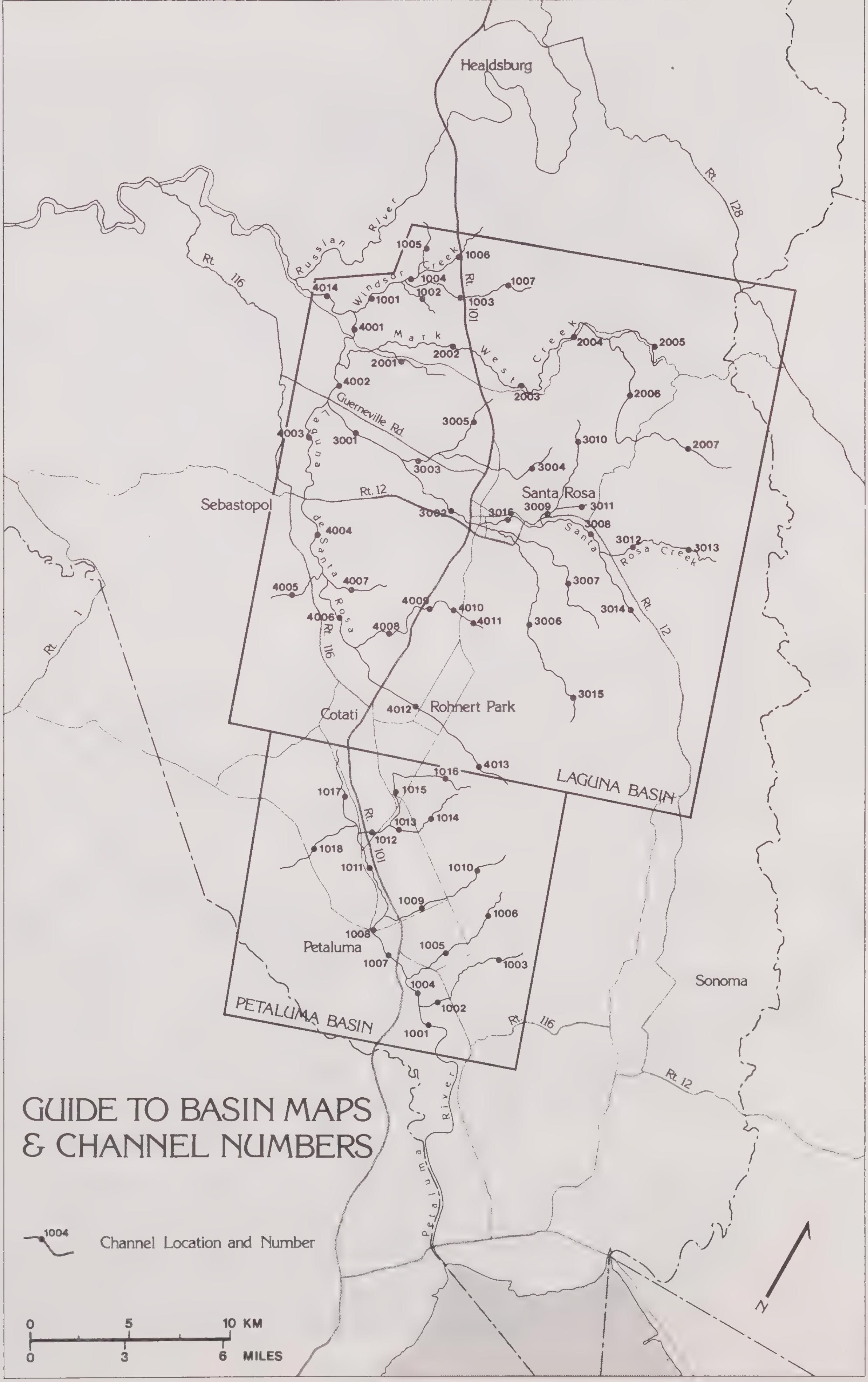

GUIDE TO BASIN MAPS
& CHANNEL NUMBERS
Channel Location and Number
1004
0 5 10 KM
0 3 6 MILES
N
LAGUNA BASIN
PETALUMA BASIN
Healdsburg
Sebastopol
Santa Rosa
Cotati
Rohnert Park
Petaluma
Sonoma
Russian River
Windsor Creek
Mark West Creek
Santa Rosa Creek
Laguna de Santa Rosa
Petaluma River
Guerneville Rd.
Rt. 101
Rt. 116
Rt. 12
Rt. 128
Rt. 1

FIG. VI-5

TABLE VI-5

LAGUNA BASIN

CHANNEL QUALITY AND POLLUTANT WASHOFF

Channel Number	Peak Concentration-TSS, mg/1 BY	CT*	SRC*	UC*	RD*	SD*	Subarea Number	Total Washoff Load - TSS, kilograms x 10^3 BY Urban	BY NonUr	CT Urban	CT NonUr	SRC Urban	SRC NonUr	UC Urban	UC NonUr	RD Urban	RD NonUr	SD Urban	SD NonUr
Windsor Creek Watershed																			
1001	202	208	213	207	118	207	1001	0.85	1.33	0.87	1.33	0.87	1.33	0.87	1.33	0.02	1.33	0.87	1.33
1002	548	550	563	550	379	550	1006	6.46	0.49	6.53	0.49	7.72	0.48	6.55	0.57	2.83	0.63	6.55	0.57
1003	63	129	109	109	117	109	1004	0.55	3.30	1.43	3.38	1.08	3.26	1.08	3.26	1.20	3.32	1.08	3.26
1004	154	197	182	227	236	227	--												
1005	165	223	208	288	294	288	1002	1.01	2.73	1.67	2.76	1.40	2.70	2.05	2.70	2.26	2.75	2.05	2.70
1006	195	230	212	212	230	212	1003	2.13	3.99	2.79	4.01	2.31	3.84	2.31	3.84	2.79	4.00	2.31	3.84
1007	39	39	39	39	39	39	1005	0.00	2.27	0.00	2.27	0.00	2.27	0.00	2.27	0.00	2.27	0.00	2.27
							TOTALS	11.00	14.11	13.29	14.24	13.38	13.88	12.86	13.97	9.10	14.30	12.86	13.97
								25.11		27.53		27.26		26.83		23.40		26.83	
Mark West Creek Watershed																			
2001	271	295	283	298	297	298	2002	1.80	3.46	2.28	3.51	2.10	3.51	2.25	3.51	2.37	3.46	2.25	3.51
2002	512	514	475	515	140	515	2001	12.81	1.01	13.45	1.04	11.35	0.94	12.91	0.95	1.01	1.15	12.91	0.90
2003	170	177	136	88	113	88	2003	2.14	3.79	2.24	3.72	1.69	3.78	1.05	4.06	1.39	4.04	1.05	4.06
2004	51	51	51	51	51	51	2004	0.00	10.24	0.00	10.24	0.00	10.24	0.00	10.24	0.00	10.24	0.00	10.24
2005	64	64	64	64	64	64	2005	0.00	12.98	0.00	12.98	0.00	12.98	0.00	12.98	0.00	12.98	0.00	12.98
2006	50	50	50	50	50	50	2006	0.00	18.20	0.00	18.20	0.00	18.20	0.00	18.20	0.00	18.20	0.00	18.20
2007	51	51	51	51	51	51	2007	0.00	18.91	0.00	18.91	0.00	18.91	0.00	18.91	0.00	18.91	0.00	18.91
2008	298	302	281	299	211	299	--												
							TOTALS	16.75	68.59	17.97	68.60	15.14	68.56	16.21	68.85	4.77	68.98	16.21	68.80
								85.34		86.57		83.70		85.06		73.75		85.01	

*County Population of 478,000

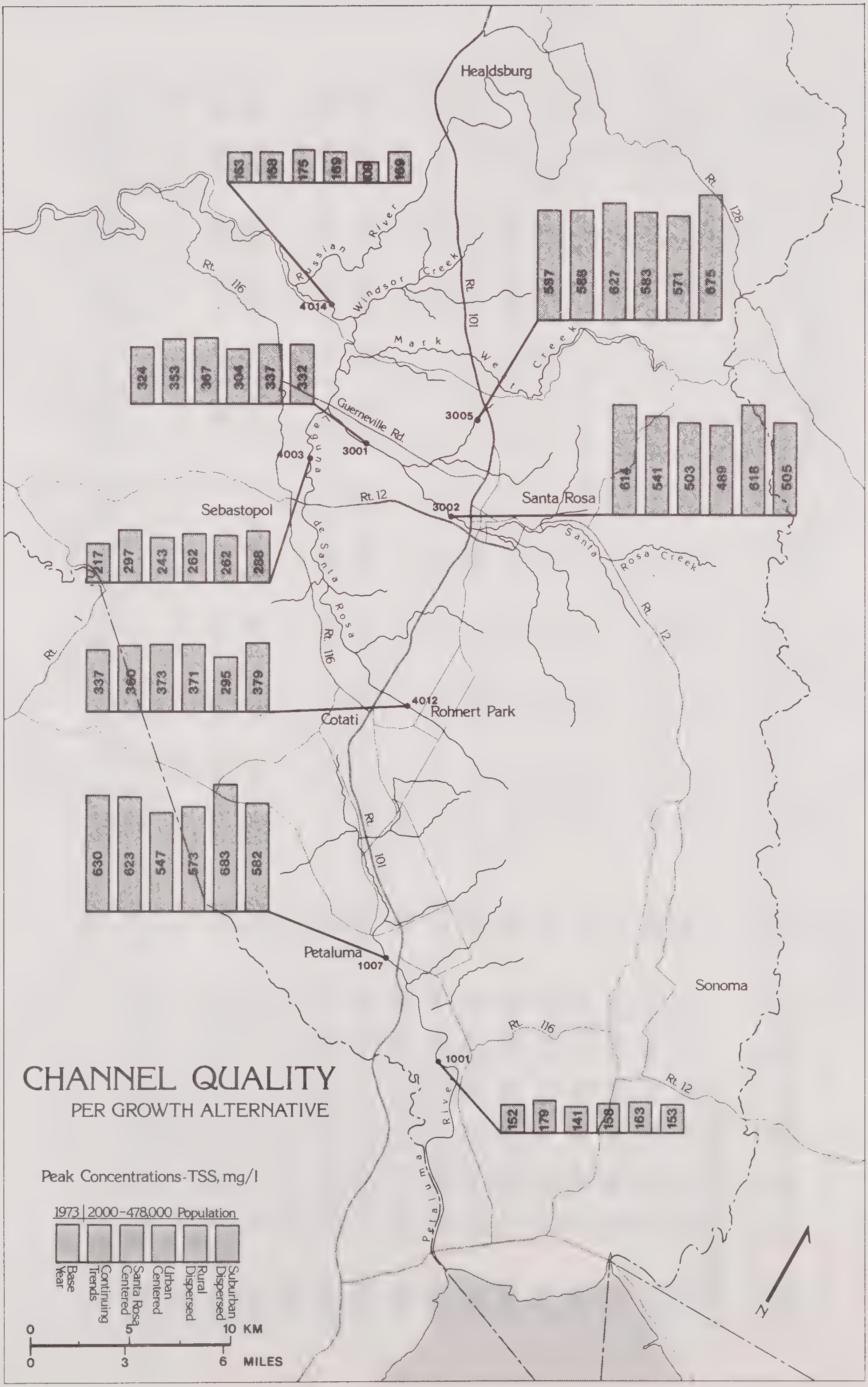
TABLE VI-5
(Continued)

Channel Number	Peak Concentration-TSS, mg/l BY	CT*	SRC*	UC*	RD*	SD*	Subarea Number	Total Washoff Load - TSS, kilograms x 10^3 BY Urban	BY NonUr	CT Urban	CT NonUr	SRC Urban	SRC NonUr	UC Urban	UC NonUr	RD Urban	RD NonUr	SD Urban	SD NonUr
Laguna de Santa Rosa Watershed																			
4001	166	176	174	165	157	172	4002	0.70	4.33	0.70	4.33	0.70	4.33	0.70	4.33	0.00	4.38	0.70	4.33
4002	219	236	237	214	229	232	4003	0.43	2.73	0.43	2.73	0.43	2.88	0.43	2.73	0.00	2.78	0.43	2.73
4003	217	297	243	262	262	288	4004,4005	0.99	8.64	8.63	8.23	5.17	7.89	5.03	8.65	5.71	8.34	7.56	8.34
4004	417	468	413	562	491	519	4006,4007	22.52	9.12	26.24	9.09	25.57	8.39	37.44	8.70	24.83	9.37	31.57	8.45
4005	314	161	161	161	76	161	4008	5.58	7.06	1.91	4.70	1.91	4.70	1.91	4.70	0.00	4.67	1.91	4.70
4006	165	186	189	203	138	196	4009	1.12	0.94	1.12	0.94	1.12	0.94	1.12	0.94	0.00	0.92	1.12	0.94
4007	557	602	452	489	530	500	4010	11.44	0.57	16.40	0.65	11.52	0.64	11.06	0.54	10.82	0.70	13.96	0.63
4008	171	229	178	201	155	324	4011	0.12	0.99	0.87	0.93	0.24	0.77	0.59	0.95	0.72	0.91	2.61	0.83
4009	320	420	354	368	216	395	4013	8.44	7.24	17.11	0.68	12.83	4.88	12.40	6.65	4.84	7.27	16.03	6.19
4010	96	69	56	96	64	106	--												
4011	111	78	63	111	72	122	4014	0.86	1.18	0.60	1.20	0.46	1.30	0.86	1.18	0.55	1.22	0.96	1.18
4012	337	360	373	391	295	379	4012	16.20	5.37	24.12	4.98	26.27	2.69	30.17	4.45	13.84	5.96	26.58	4.83
4013	29	29	29	29	29	29	4015	0.00	0.24	0.00	2.38	0.00	2.38	0.00	2.38	0.00	2.38	0.00	2.38
4014	163	168	175	169	109	169	4001	0.37	1.95	0.37	1.95	0.37	1.95	0.37	1.95	0.00	1.95	0.37	1.95
							TOTALS	68.77	50.36	98.50	42.79	81.59	43.74	102.08	48.15	60.77	50.85	103.80	47.48
								119.13		141.29		130.33		150.23		111.62		151.28	
							BASIN TOTALS (478,000 pop.)	356.26		401.11		395.25		382.43		339.73		400.06	
							BASIN TOTALS (630,000 pop.)			445.50		445.50		414.10		(no simulation)		453.50	

TABLE VI-5

(Continued)

Channel Number	Peak Concentration-TSS, mg/l BY	CT*	SRC*	UC*	RD*	SD*	Subarea Number	Total Washoff Load - TSS, kilograms x 10^3 BY Urban	BY NonUr	CT Urban	CT NonUr	SRC Urban	SRC NonUr	UC Urban	UC NonUr	RD Urban	RD NonUr	SD Urban	SD NonUr
Santa Rosa Creek Watershed																			
3001	324	353	367	304	337	332	3001	2.87	1.86	4.27	1.91	5.85	2.18	2.95	1.87	2.75	1.95	3.34	2.01
3002	614	541	503	489	618	505	3004	28.82	0.75	26.78	0.99	29.80	0.52	21.89	0.71	31.72	1.28	23.43	0.58
3003	441	491	466	448	453	524	--												
3004	461	520	549	546	476	533	3003	8.44	1.26	13.55	1.39	12.15	1.31	10.26	1.34	9.55	1.39	13.92	1.36
3005	587	588	627	583	571	675	3002	7.69	2.86	18.37	2.50	24.66	1.82	14.98	2.28	10.35	3.07	22.45	2.66
3006	247	212	259	198	243	200	3009	4.47	1.76	4.06	1.77	5.72	1.74	3.03	1.80	4.33	1.78	3.15	1.81
3007	457	492	359	316	480	340	3008	9.59	0.99	11.55	1.01	8.08	0.81	5.00	0.86	9.55	0.92	5.47	0.91
3008	363	303	318	321	327	352	3005	6.98	0.96	6.44	1.16	6.74	0.95	5.50	0.91	5.04	1.02	6.41	0.90
3009	235	235	275	186	140	203	--												
3010	80	136	209	128	47	163	3007	0.73	3.36	1.63	3.11	2.60	3.03	1.23	3.02	0.34	3.61	1.89	3.00
3011	343	323	355	246	210	263	3006	4.13	1.57	4.79	1.52	5.38	1.44	2.85	1.60	2.01	1.68	3.13	1.59
3012	58	58	58	58	58	58	--												
3013	58	58	58	58	58	58	3012	0.00	24.05	0.00	24.05	0.00	24.05	0.00	24.05	0.00	24.05	0.00	24.05
3014	64	194	260	154	148	224	3011	0.92	7.22	3.07	6.40	4.17	5.56	2.42	6.36	2.31	7.05	3.59	5.84
3015	57	57	57	57	52	57	3010	0.55	4.85	0.55	4.85	0.55	4.85	0.55	4.85	0.00	5.21	0.55	4.85
3016	268	233	256	230	228	250	--												
							TOTALS	$\underbrace{75.19 \quad 51.49}_{126.68}$		$\underbrace{95.06 \quad 50.66}_{145.72}$		$\underbrace{105.70 \quad 48.26}_{153.96}$		$\underbrace{70.66 \quad 49.65}_{120.31}$		$\underbrace{77.95 \quad 53.01}_{130.96}$		$\underbrace{87.38 \quad 49.56}_{136.94}$	



Healdsburg
Rt. 128
175
169
Russian River
Rt. 116
Windsor Creek
Rt. 101
4014
587
568
627
583
571
675
Mark West Creek
324
353
367
304
337
332
Guerneville Rd.
3005
3001
4003
Laguna de Santa Rosa
Rt. 12
3002
Santa Rosa
541
503
489
618
505
Sebastopol
217
297
243
262
262
288
Santa Rosa Creek
Rt. 12
Rt. 1
Rt. 116
337
360
373
371
295
379
4012
Rohnert Park
Cotati
630
623
547
573
683
582
Rt. 101
Petaluma
1007
Sonoma
Rt. 116
1001
Rt. 12
CHANNEL QUALITY
PER GROWTH ALTERNATIVE
152
179
141
158
163
153
Petaluma River
Peak Concentrations-TSS, mg/l
1973 | 2000-478,000 Population
Base Year
Continuing Trends
Santa Rosa Centered
Urban Centered
Rural Dispersed
Suburban Dispersed
0
5
10 KM
0
3
6 MILES
N

FIG. VI-7

The peak concentrations in Table VI-5 are highest in those channels which drain subareas with the largest urban development concentrations and hence the largest urban washoff loads. The pollutant load in urban areas is picked up early in the storm causing the concentration of total suspended solids in channels draining urban areas to peak faster and higher than those draining rural areas. In the rural areas the intensity of rainfall and slope are major determinants of how much material is eroded off the watershed. The storm used in these simulations has a peak intensity at 1-1/2 hours after the storm begins. Consequently, the majority of erosion occurs when flows are highest, resulting in lower peak concentrations at a later time in the storm for channels draining rural areas.

The washoff loads in the Laguna Basin under Base Year conditions are distributed between urban and nonurban areas as follows:

	Percent Washoff Load	
Windsor Creek	50% urban	50% nonurban
Mark West Creek	20% urban	80% nonurban
Santa Rosa Creek	60% urban	40% nonurban
Laguna de Santa Rosa	60% urban	40% nonurban

In terms of the overall impact of the different growth patterns on wet weather quality, Table VI-5 indicates the following for a County population of 478,000:

Windsor Creek	- all alternatives have about the same impact
Mark West Creek	- Rural Dispersed results in the lowest washoff load because it has the lowest amount of urban development for that watershed of any alternatives
Santa Rosa Creek	- Urban Centered results in the lowest washoff load because it has the lowest amount of development for that watershed of any alternative
Laguna de Santa Rosa	- Rural Dispersed results in the lowest washoff load because it has the lowest amount of urban development for that watershed of any alternative

For the entire Laguna Basin, Table VI-5 shows the Rural Dispersed alternative producing the lowest washoff load. The greatest impact on Russian River wet weather quality, at the 478,000 population levels, would result from the Continuing Trends pattern, although it is virtually the same as Santa Rosa Centered and Suburban Dispersed and only five percent greater than Urban Centered. Population levels of 630,000 for Sonoma County produce loads about 10 percent greater than the 478,000 level. Urban Centered results in the lowest total suspended solids load at the 630,000 level.

Some caution is necessary when reviewing the Rural Dispersed figures. Their relative position to the other growth alternatives is correct but their exact quantities, particulary when measured against Base Year, can cause confusion. This is due both to slightly different land use categorizations between Base Year and the growth alternatives and the way the runoff model treats the pollution runoff from the "ranchette" residential uses that dominated Rural Dispersed. Because the "ranchettes" are built at one unit per three acres and would have a very low percentage impervious coverage, the model treats them as open space. Unfortunately, there was no information from which to determine an appropriate pollutant load for ranchettes, and the open space load may be too low for particular pollutants.

Figures VI-8 and VI-9 illustrate the impact of urban land uses on the peak concentrations of total suspended solids in the channels. The figures for Base Year and Santa Rosa Centered 478 show the impact of urban washoff loads on peak concentrations of total suspended solids in channels and the dilution effects of rural runoff as these streams are combined with flows from urban areas. In order to characterize quality in channels draining urban and nonurban areas, Figures VI-10 and VI-11 are copies of the simulations for Santa Rosa Centered 478 for channel 3002 (Santa Rosa Creek in downtown Santa Rosa) and channel 3015 (upper reach of Matanzas Creek). The quality of channel 3002 reflects the influence of urban development and channel 3015 runs through an open area unaffected by urban development.

Without exception, the peak concentrations of all eight water quality parameters are higher in those channels affected by urban runoff than those draining rural areas. Also, on the recession limb of the storm, (the last part of the storm following the peak), concentrations are higher in the urban channel 3002 than in the rural 3015.

Impact of Sewage Treatment Plants During Wet Weather Periods

The discharges from sewage treatment plants are not included in the Runoff-Quality Model. During peak runoff periods, the impact of these point discharges would have very little effect on the channel qualities. The peak flow in the Laguna de Santa Rosa at the proposed consolidated Laguna sewage treatment plant (STP) discharge location was 20 m^3/sec compared to a dry weather flow of 1.13 m^3/sec for the consolidated Laguna STP.

However, after the channel flows have peaked and are receeding, the STP flows become significant due to infiltration into the sewer lines and interceptors serving the plant. In order to assess the impact of wet weather flows from the Laguna STP, a simulation was made with QUAL-II using the channel flow and quality on the recession limb of the storm from the Runoff-Quality Model as input to the QUAL-II Model.

The flow at the STP was assumed to double during wet weather. This assumption is based on comparisons of dry weather flows to wet weather flows at existing STP's in the Santa Rosa area. The quality of the

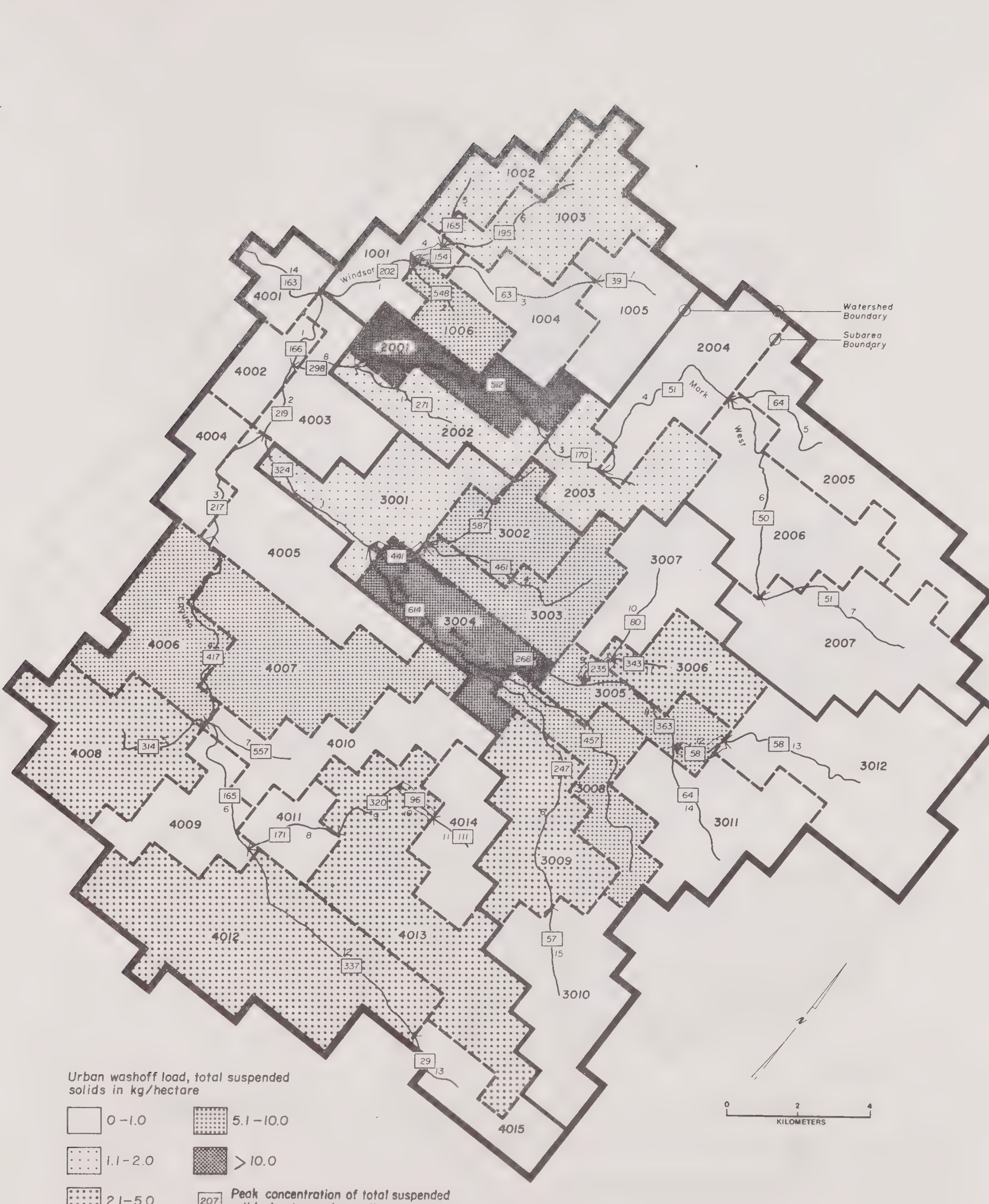


FIG. VI–8

LAGUNA BASIN - BASE YEAR

URBAN WASHOFF AND CHANNEL QUALITIES

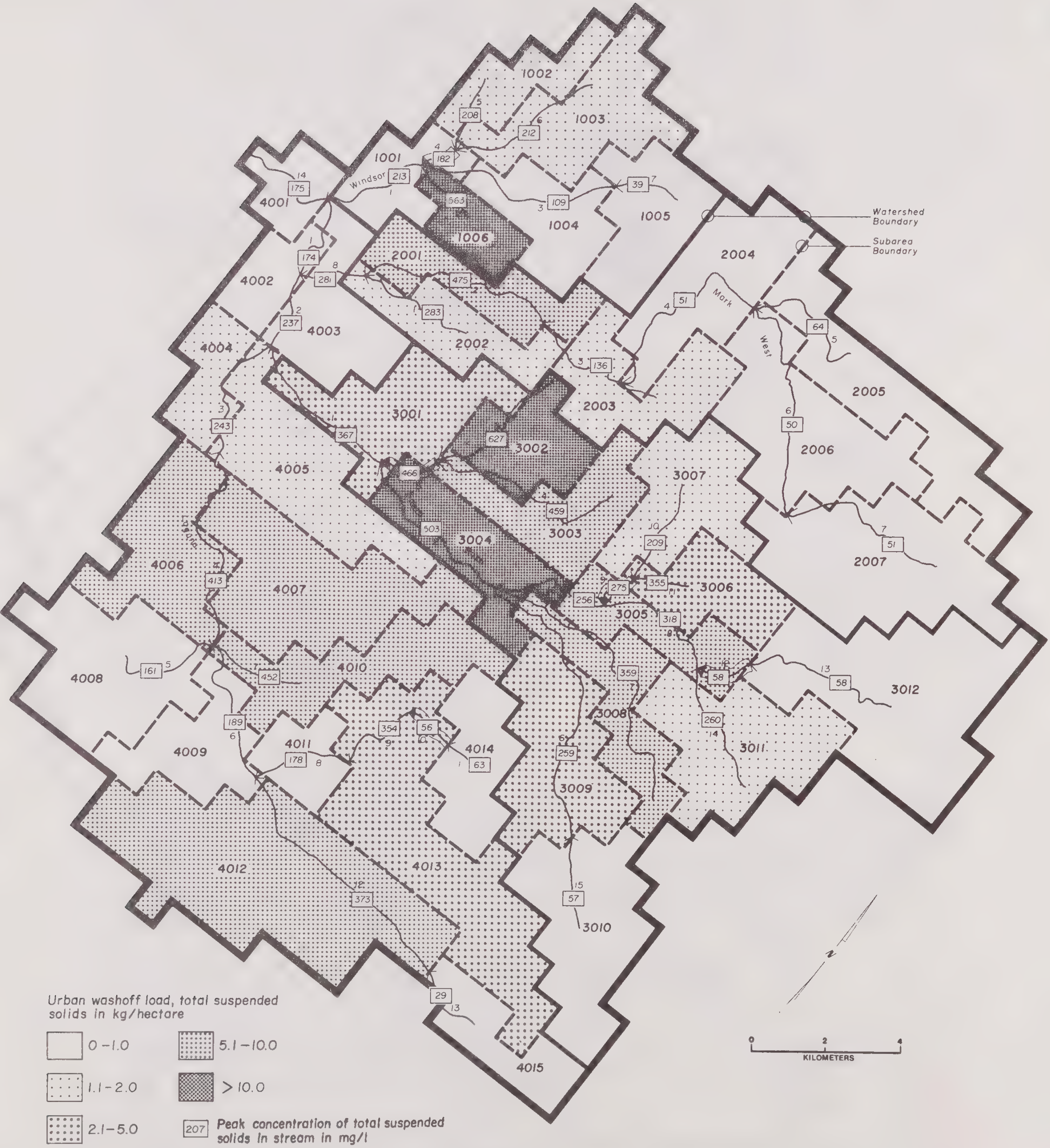


FIG. VI-9

LAGUNA BASIN - SRC-478

URBAN WASHOFF AND CHANNEL QUALITIES

LAGUNA BASIN
SANTA ROSA CENTERED 478

SUMMARY OF QUANTITY AND QUALITY RESULTS AT LOCATION 3002

FLOW IN CMS AND QUALITY IN (MG/L) EXCEPT COLIFORMS IN (NUMBERS/100ML)

TIME	FLOW	TOT-SS	NON-SET	BOD	GREASE	F-COLI	TOT-N	TOT-P	HVY MET
0 .00	.000	.0	.0	.0	.00	0.00	.00	.00	.00
0 15.00	.000	.0	.0	.0	.00	0.00	.00	.00	.00
0 30.00	.000	.0	.0	.0	.00	0.00	.00	.00	.00
0 45.00	.000	.0	.0	.0	.00	0.00	.00	.00	.00
1 .00	.004	196.3	115.1	16.7	20.53	1.85+04	33.37	4.29	11.77
1 15.00	.034	444.2	260.1	37.8	46.45	4.21+04	75.61	9.73	26.62
1 30.00	.165	503.3	294.2	42.9	52.62	4.81+04	85.84	11.05	30.13
1 45.00	.757	498.8	291.2	42.5	52.09	4.80+04	85.13	10.96	29.81
2 .00	3.199	451.3	263.1	38.4	47.00	4.37+04	76.99	9.91	26.89
2 15.00	9.321	373.4	217.0	31.7	38.68	3.65+04	63.61	8.19	22.10
2 30.00	19.529	296.2	171.4	25.0	30.38	2.94+04	50.29	6.47	17.34
2 45.00	32.493	236.0	136.0	19.7	23.81	2.36+04	39.70	5.11	13.57
3 .00	46.164	191.3	109.9	15.6	18.82	1.91+04	31.64	4.06	10.72
3 15.00	58.757	157.7	90.5	12.5	15.00	1.56+04	25.42	3.26	8.55
3 30.00	69.261	132.2	75.9	10.0	12.02	1.27+04	20.55	2.63	6.85
3 45.00	77.396	112.5	64.7	8.1	9.66	1.04+04	16.70	2.13	5.52
4 .00	83.280	97.2	56.0	6.5	7.79	8.61+03	13.62	1.73	4.46
4 15.00	86.988	85.4	49.3	5.3	6.30	7.15+03	11.18	1.41	3.62
4 30.00	88.428	76.4	44.2	4.3	5.13	6.01+03	9.27	1.16	2.96
4 45.00	87.681	69.6	40.5	3.5	4.22	5.12+03	7.78	.96	2.45
5 .00	85.036	64.6	37.7	3.0	3.52	4.45+03	6.65	.82	2.05
5 15.00	80.893	60.9	35.6	2.5	2.99	3.94+03	5.79	.70	1.76
5 30.00	75.765	58.1	34.1	2.2	2.59	3.56+03	5.14	.62	1.53
5 45.00	70.002	55.9	32.8	1.9	2.28	3.27+03	4.64	.55	1.35
6 .00	63.802	54.1	31.8	1.7	2.03	3.03+03	4.24	.50	1.22
6 15.00	57.518	52.5	30.9	1.6	1.84	2.84+03	3.91	.46	1.10
6 30.00	51.515	51.1	30.1	1.4	1.67	2.68+03	3.64	.42	1.01
6 45.00	45.977	49.8	29.3	1.3	1.54	2.54+03	3.41	.39	.93
7 .00	40.968	48.5	28.6	1.2	1.42	2.41+03	3.21	.37	.87
7 15.00	36.486	47.3	27.9	1.2	1.32	2.31+03	3.04	.34	.81
7 30.00	32.505	46.1	27.3	1.1	1.24	2.21+03	2.89	.33	.76
7 45.00	28.981	45.0	26.6	1.0	1.17	2.12+03	2.76	.31	.72
8 .00	25.869	43.9	26.0	1.0	1.11	2.05+03	2.64	.30	.69
8 15.00	23.125	42.8	25.3	.9	1.05	1.98+03	2.54	.28	.65
8 30.00	20.707	41.8	24.7	.9	1.01	1.91+03	2.45	.27	.63
8 45.00	18.578	40.8	24.1	.9	.97	1.85+03	2.36	.26	.60
9 .00	16.704	39.8	23.5	.8	.93	1.80+03	2.29	.25	.58

FIG. VI-10

LAGUNA BASIN

QUALITY RESULTS AT CHANNEL 3002

LAGUNA BASIN
SANTA ROSA CENTERED 478

SUMMARY OF QUANTITY AND QUALITY RESULTS AT LOCATION 3015

FLOW IN CMS AND QUALITY IN (MG/L) EXCEPT COLIFORMS IN (NUMBERS/100ML)

	TIME	FLOW	TOT-SS	NON-SET	BOD	GREASE	F-COLI	TOT-N	TOT-P	HVY MET
0	.00	.000	.0	.0	.0	.00	0.00	.00	.00	.00
0	15.00	.000	.0	.0	.0	.00	0.00	.00	.00	.00
0	30.00	.000	.0	.0	.0	.00	0.00	.00	.00	.00
0	45.00	.042	15.9	10.2	1.1	2.09	2.03+03	2.94	.43	1.08
1	.00	.328	36.5	23.5	2.4	4.52	4.44+03	6.42	.94	2.35
1	15.00	.970	42.7	27.2	2.5	4.75	4.78+03	6.85	1.00	2.48
1	30.00	1.792	43.6	27.7	2.3	4.39	4.52+03	6.43	.93	2.30
1	45.00	3.796	48.0	30.1	1.9	3.63	4.04+03	5.59	.79	1.92
2	.00	8.300	55.6	34.2	1.4	2.51	3.35+03	4.39	.58	1.37
2	15.00	11.388	57.2	34.9	.9	1.57	2.65+03	3.27	.40	.90
2	30.00	10.732	54.5	33.0	.6	1.05	2.17+03	2.56	.29	.63
2	45.00	9.599	51.9	31.3	.5	.73	1.86+03	2.10	.22	.46
3	.00	9.087	50.1	30.2	.4	.50	1.64+03	1.79	.18	.35
3	15.00	8.765	49.0	29.5	.3	.36	1.50+03	1.59	.15	.28
3	30.00	8.520	48.2	29.0	.2	.27	1.41+03	1.45	.13	.23
3	45.00	8.274	47.5	28.5	.2	.21	1.34+03	1.37	.12	.20
4	.00	8.009	46.9	28.1	.2	.17	1.30+03	1.31	.11	.18
4	15.00	7.387	45.7	27.4	.2	.15	1.25+03	1.25	.10	.16
4	30.00	6.211	43.4	26.1	.2	.13	1.18+03	1.17	.09	.15
4	45.00	4.939	40.4	24.3	.1	.12	1.09+03	1.08	.09	.13
5	.00	3.908	37.2	22.3	.1	.10	1.00+03	.99	.08	.12
5	15.00	3.083	33.9	20.3	.1	.09	9.13+02	.90	.07	.11
5	30.00	2.412	30.5	18.3	.1	.08	8.20+02	.81	.06	.10
5	45.00	1.861	27.1	16.3	.1	.07	7.30+02	.72	.06	.09
6	.00	1.410	24.4	14.6	.1	.07	6.56+02	.65	.05	.08
6	15.00	1.047	22.7	13.6	.1	.06	6.12+02	.60	.05	.07
6	30.00	.763	22.1	13.3	.1	.06	5.96+02	.59	.05	.07
6	45.00	.559	22.0	13.2	.1	.06	5.91+02	.58	.05	.07
7	.00	.424	21.8	13.1	.1	.06	5.87+02	.58	.05	.07
7	15.00	.330	21.6	13.0	.1	.06	5.83+02	.58	.05	.07
7	30.00	.263	21.5	12.9	.1	.06	5.79+02	.57	.05	.07
7	45.00	.213	21.4	12.8	.1	.06	5.76+02	.57	.04	.07
8	.00	.176	21.2	12.7	.1	.06	5.72+02	.57	.04	.07
8	15.00	.147	21.1	12.7	.1	.06	5.69+02	.56	.04	.07
8	30.00	.125	21.0	12.6	.1	.06	5.66+02	.56	.04	.07
8	45.00	.107	20.9	12.5	.1	.06	5.63+02	.56	.04	.07
9	.00	.092	20.8	12.5	.1	.06	5.60+02	.55	.04	.07

FIG.VI–11

LAGUNA BASIN

QUALITY RESULTS AT CHANNEL 3015

effluent from the Laguna plant was set to reflect a lower level of treatment to approximate a condition of plant overloading during wet weather. The dissolved oxygen concentrations of the headwaters were set at 5.0 mg/1 and, as explained previously, other headwater quality parameters such as BOD, were specified at those concentrations resulting from the Runoff-Quality Model simulation of the Santa Rosa Centered 478 pattern.

The QUAL-II "wet weather" simulation shows that the Laguna plant would cause a noticeable impact on the quality of water in the Laguna de Santa Rosa during storm periods when the plant was discharging at a wet weather flow rate of 2.3 m^3/sec with effluent quality of 50 mg/1 of BOD and 150 mg/1 or suspended solids. A DO sag was observed beginning at the plant discharge and extending to the confluence of Santa Rosa Creek and the Laguna. DO was 5.62 mg/1 at the discharge location and declined to 3.95 mg/1 at Santa Rosa Creek.

Petaluma Basin

The Petaluma Basin is represented by an area of 189 square kilometers in the Runoff-Quality Model. The drainage area of the river downstream from the City of Petaluma was not included in the model. Since no growth was allowed in this area in any of the land use alternatives, there will be no change in the quality of runoff to the Petaluma River below the downstream limit of the model.

The Petaluma Basin is broken down into 15 subareas and 18 channels which are shown in Figure VI-12.

Table VI-6 shows the peak concentrations of total suspended solids for each channel in the Petaluma Basin and the total suspended solids washed off the subareas. Rural Dispersed results in the lowest total suspended solids washoff. However, it was pointed out earlier that the way in which rural residential development was treated by the model calls for care to be taken in drawing conclusions about the impacts of this pattern on wet weather quality. The washoff from Santa Rosa Centered alternative is so close to that of Rural Dispersed that Santa Rosa Centered is likely to have a lesser impact on wet weather quality. Also, at the 630,000 population level, the Santa Rosa Centered alternative results in the lowest total suspended solids washoff load.

Figures VI-13 and VI-14 show the impact of urban land uses on peak concentrations of total suspended solids in the Petaluma Basin channels and the dilution effects of rural runoff where these streams are combined with runoff from urban areas. Figures 15 and 16 illustrate the quality of runoff in a channel draining an urban area and a channel draining an area unaffected by development. Channel 1007 is the Petaluma River at the City of Petaluma and channel 1010 is the headwater reach of Washington Creek. There is no urban load affecting the quality of runoff in channel 1010.

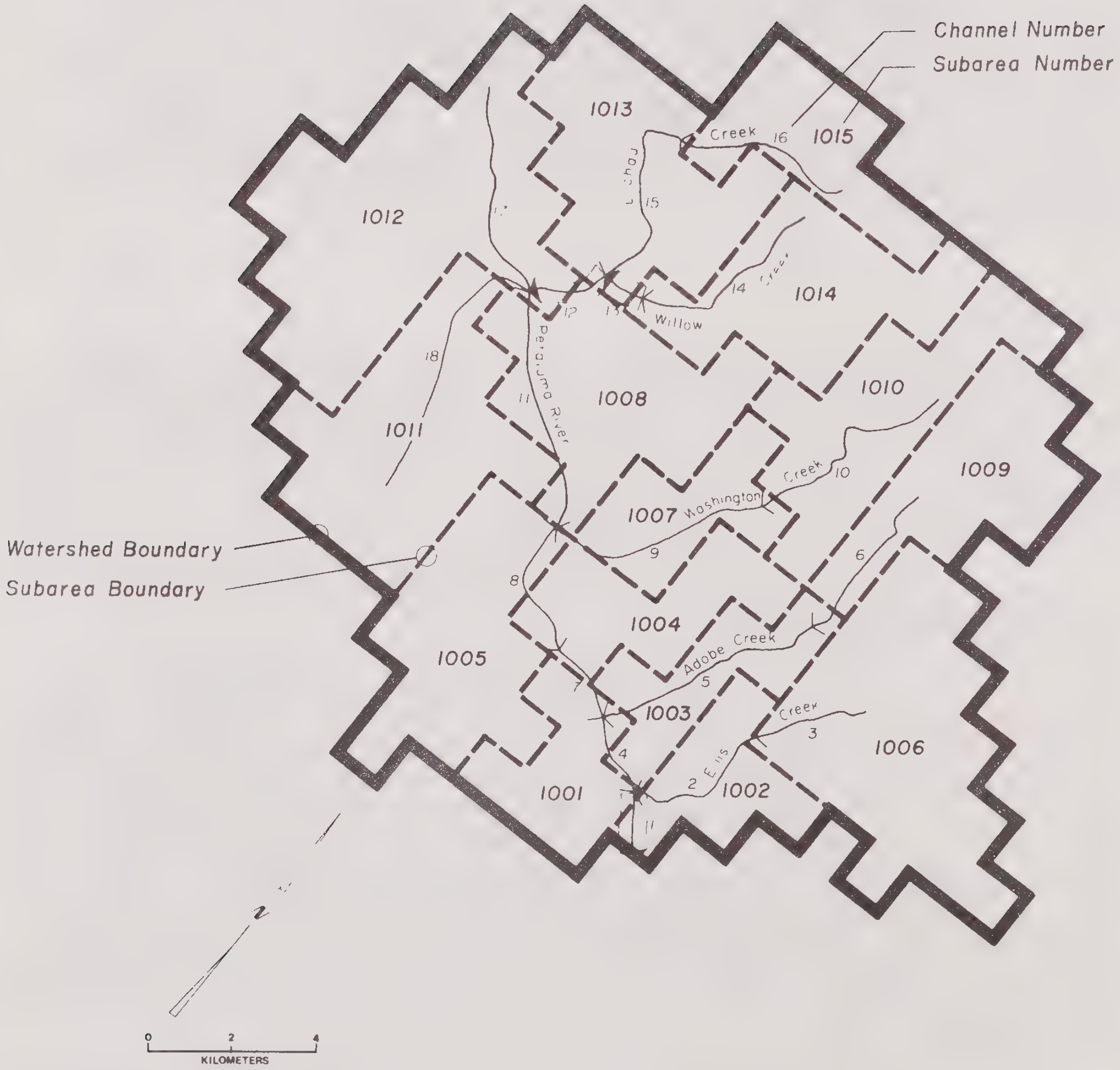


FIG. VI–12

PETALUMA BASIN

SUBAREAS AND CHANNELS

TABLE VI-6

PETALUMA BASIN

CHANNEL QUALITY AND POLLUTANT WASHOFF

Channel Number	Peak Concentration-TSS, mg/l BY	CT*	SRC*	UC*	RD*	SD*	Subarea Number	Total Washoff Load - TSS, kilograms x 10^3 BY Urban	BY NonUr	CT Urban	CT NonUr	SRC Urban	SRC NonUr	UC Urban	UC NonUr	RD Urban	RD NonUr	SD Urban	SD NonUr
1001	152	179	141	158	163	153	--												
1002	61	61	61	61	61	61	1002	0.00	1.75	0.29	1.36	0.02	1.72	0.04	1.69	0.00	1.75	0.65	1.12
1003	58	58	58	58	58	58	1006	0.00	4.35	0.00	4.35	0.00	4.35	0.00	4.35	0.00	4.35	0.00	4.35
1004	375	392	280	247	399	269	1001	2.37	0.21	3.17	0.24	1.52	0.20	1.18	0.20	2.77	0.23	1.69	0.21
1005	109	157	161	198	99	190	1003	1.07	1.09	2.37	0.98	2.35	0.94	3.30	0.77	0.97	1.11	3.31	0.71
1006	45	45	45	45	45	45	1009	0.00	3.84	0.00	3.84	0.00	3.84	0.00	3.84	0.00	3.84	0.00	3.84
1007	630	623	547	573	683	582	1004	9.03	0.61	10.90	0.78	9.63	0.54	12.10	0.56	11.40	0.98	9.57	0.65
1008	562	542	416	436	541	587	1005	12.70	0.31	12.75	0.45	8.38	0.35	11.20	0.35	11.30	0.41	10.50	0.41
1009	130	163	207	239	164	243	1007	1.70	1.42	2.78	1.38	4.32	1.31	5.38	1.34	2.59	1.43	5.44	1.26
1010	41	41	41	41	41	41	1010	0.00	6.39	0.00	6.39	0.00	6.39	0.00	6.39	0.00	6.39	0.00	6.39
1011	381	416	432	427	248	446	1008	4.83	1.59	8.51	1.64	7.86	1.59	12.10	1.10	9.29	1.64	11.80	1.39
1012	127	130	127	103	85	103	--												
1013	88	88	88	88	91	88	--												
1014	88	88	88	88	91	83	1014	0.37	9.66	0.37	9.66	0.37	9.66	0.37	9.66	0.00	10.10	0.37	9.66
1015	246	255	247	190	83	190	1013	2.43	5.42	2.70	5.12	2.53	4.22	1.90	5.49	0.20	6.51	1.90	5.49
1016	228	91	137	137	94	137	1015	1.52	7.70	0.23	6.97	0.88	6.53	0.88	6.53	0.00	7.32	0.88	6.53
1017	200	200	294	200	40	280	1012	2.95	3.58	2.95	3.58	4.37	3.09	2.95	3.58	0.00	4.58	4.15	3.11
1018	187	198	221	230	48	428	1011	2.01	2.28	2.13	2.21	2.39	2.13	2.48	2.05	0.37	3.00	4.64	1.46
								41.00	50.20	49.10	49.00	44.60	46.90	53.80	47.90	35.90	53.70	54.90	46.60
							BASIN TOTALS (478,000 pop.)	91.20		98.10		91.50		101.70		89.60		101.50	
							BASIN TOTALS (630,000 pop.)			112.59		95.02		116.64		(no simulation)		106.57	

*County Population of 478,000.

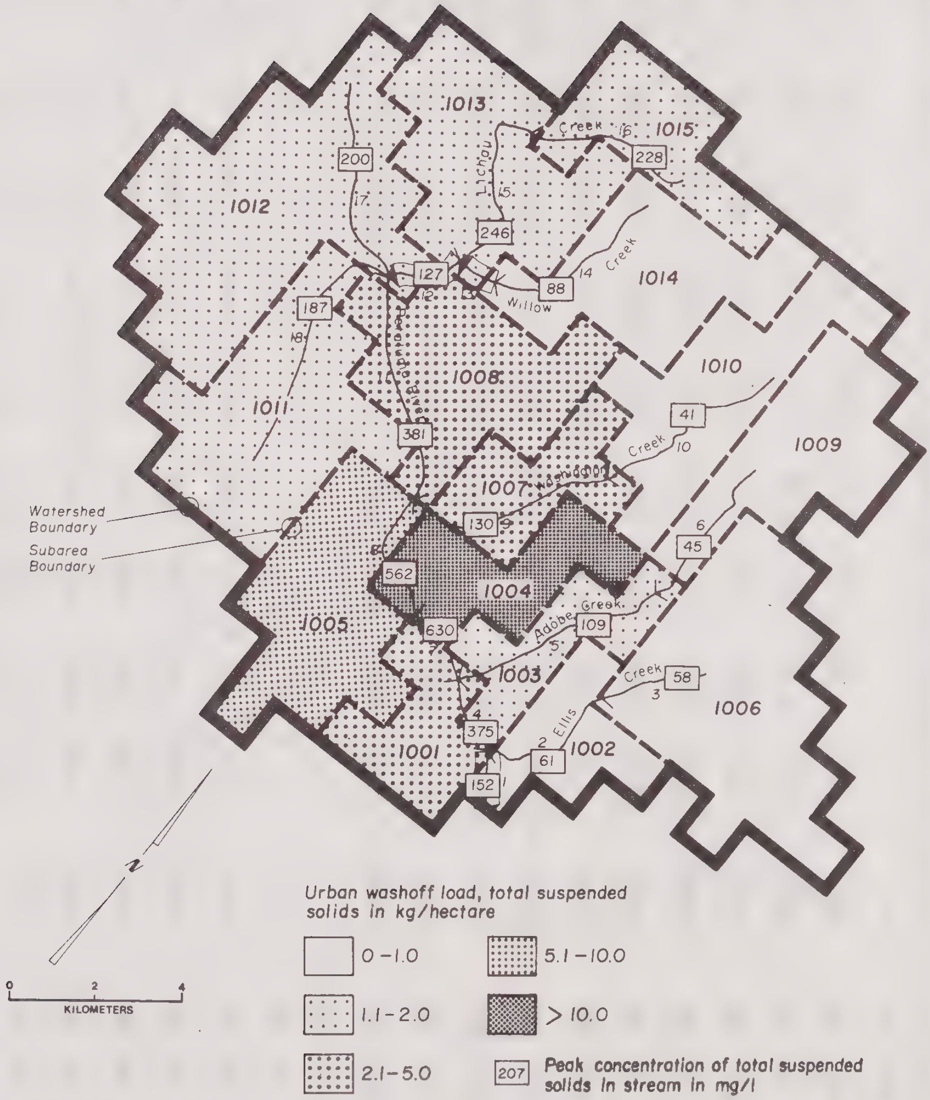


FIG. VI-13

PETALUMA BASIN - BASE YEAR

URBAN WASHOFF AND CHANNEL QUALITIES

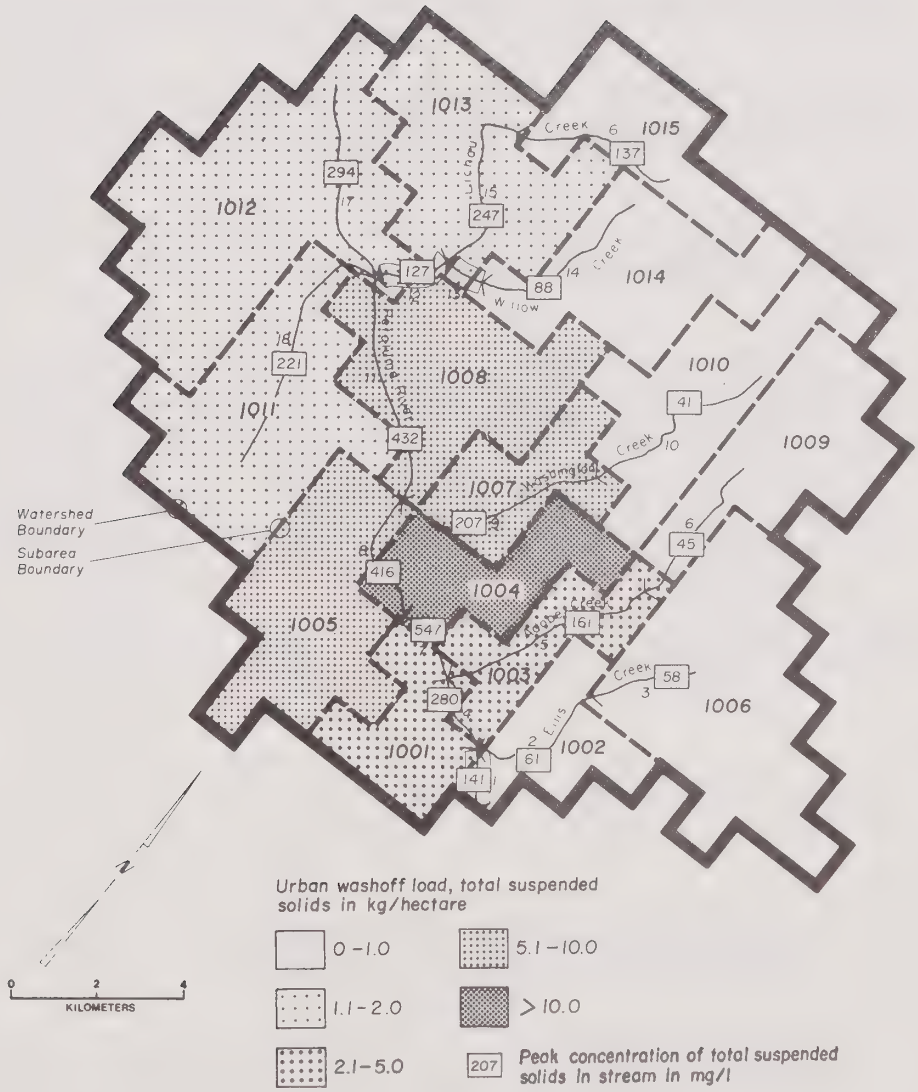


FIG. VI-14

PETALUMA BASIN - SRC-478

URBAN WASHOFF AND CHANNEL QUALITIES

PETALUMA BASIN
SRC-47B

SUMMARY OF QUANTITY AND QUALITY RESULTS AT LOCATION 1007

FLOW IN CMS AND QUALITY IN (MG/L) EXCEPT COLIFORMS IN (NUMBERS/100ML)

TIME	FLOW	TOT-SS	NON-SET	BOD	GREASE	F-COLI	TOT-N	TOT-P	HVY MET
0 .00	.000	.0	.0	.0	.00	0.00	.00	.00	.00
0 15.00	.000	.0	.0	.0	.00	0.00	.00	.00	.00
0 30.00	.000	.0	.0	.0	.00	0.00	.00	.00	.00
0 45.00	.000	.0	.0	.0	.00	0.00	.00	.00	.00
1 .00	.000	207.6	125.4	15.9	23.24	1.80+04	36.42	4.89	13.25
1 15.00	.006	470.3	283.8	36.0	52.60	4.08+04	82.49	11.06	29.98
1 30.00	.033	538.9	324.6	41.3	60.16	4.70+04	94.53	12.66	34.30
1 45.00	.173	547.2	328.8	42.1	60.75	4.79+04	95.79	12.81	34.65
2 .00	.806	513.4	307.3	39.5	56.41	4.51+04	89.43	11.92	32.20
2 15.00	2.361	446.9	266.0	34.6	48.42	3.97+04	77.41	10.27	27.66
2 30.00	4.801	375.2	221.7	29.2	39.95	3.38+04	64.57	8.52	22.85
2 45.00	7.952	313.3	183.6	24.6	32.68	2.86+04	53.43	7.00	18.72
3 .00	11.821	262.0	152.6	20.5	26.68	2.40+04	44.10	5.75	15.30
3 15.00	16.397	220.5	128.0	17.1	21.82	2.01+04	36.39	4.72	12.53
3 30.00	21.521	187.3	108.6	14.2	17.92	1.67+04	30.09	3.88	10.31
3 45.00	26.875	161.2	93.7	11.7	14.82	1.39+04	25.02	3.22	8.55
4 .00	32.080	140.8	82.1	9.7	12.37	1.15+04	20.96	2.69	7.15
4 15.00	36.677	125.0	73.2	8.1	10.43	9.64+03	17.74	2.27	6.04
4 30.00	40.215	112.8	66.5	6.9	8.90	8.15+03	15.20	1.94	5.17
4 45.00	42.520	103.6	61.3	5.9	7.69	6.98+03	13.20	1.68	4.48
5 .00	43.646	96.5	57.4	5.1	6.73	6.07+03	11.62	1.47	3.93
5 15.00	43.721	90.9	54.3	4.4	5.95	5.34+03	10.35	1.31	3.49
5 30.00	42.934	86.5	51.8	3.9	5.31	4.77+03	9.32	1.17	3.13
5 45.00	41.502	83.0	49.8	3.5	4.78	4.30+03	8.48	1.06	2.83
6 .00	39.629	80.1	48.1	3.1	4.34	3.93+03	7.78	.97	2.57
6 15.00	37.488	77.7	46.7	2.8	3.96	3.62+03	7.19	.89	2.36
6 30.00	35.216	75.6	45.5	2.6	3.64	3.36+03	6.68	.82	2.17
6 45.00	32.910	73.7	44.4	2.4	3.36	3.15+03	6.25	.77	2.01
7 .00	30.641	72.1	43.5	2.2	3.12	2.96+03	5.87	.72	1.88
7 15.00	28.452	70.6	42.6	2.1	2.90	2.80+03	5.54	.67	1.75
7 30.00	26.374	69.2	41.8	1.9	2.71	2.66+03	5.25	.63	1.64
7 45.00	24.421	68.0	41.0	1.8	2.54	2.53+03	4.98	.60	1.55
8 .00	22.601	66.8	40.3	1.7	2.39	2.42+03	4.75	.57	1.46
8 15.00	20.915	65.6	39.6	1.6	2.25	2.32+03	4.53	.54	1.38
8 30.00	19.357	64.4	38.9	1.5	2.13	2.23+03	4.34	.51	1.31
8 45.00	17.920	63.3	38.2	1.4	2.01	2.15+03	4.16	.49	1.24
9 .00	16.595	62.3	37.6	1.4	1.91	2.07+03	3.99	.47	1.18

FIG. VI-15

PETALUMA BASIN

QUALITY RESULTS AT CHANNEL 1007

PETALUMA BASIN
SRC-478

SUMMARY OF QUANTITY AND QUALITY RESULTS AT LOCATION 1010

FLOW IN CMS AND QUALITY IN (MG/L) EXCEPT COLIFORMS IN (NUMBERS/100ML)

TIME	FLOW	TOT-SS	NON-SET	BOD	GREASE	F-COLI	TOT-N	TOT-P	HVY MET
0 .00	.000	.0	.0	.0	.00	0.00	.00	.00	.00
0 15.00	.000	.0	.0	.0	.00	0.00	.00	.00	.00
0 30.00	.000	.0	.0	.0	.00	0.00	.00	.00	.00
0 45.00	.100	2.3	1.4	.0	.01	5.94+01	.06	.00	.01
1 .00	.403	5.3	3.2	.0	.01	1.35+02	.14	.01	.02
1 15.00	.850	6.8	4.1	.0	.02	1.73+02	.18	.01	.02
1 30.00	1.341	8.3	5.0	.0	.02	2.10+02	.22	.02	.02
1 45.00	2.871	15.3	9.2	.0	.03	3.87+02	.40	.03	.05
2 .00	7.052	27.1	16.2	.1	.06	6.85+02	.70	.05	.08
2 15.00	11.236	34.3	20.6	.1	.08	8.69+02	.89	.07	.10
2 30.00	13.311	37.2	22.3	.1	.08	9.42+02	.97	.07	.11
2 45.00	14.769	39.0	23.4	.1	.09	9.88+02	1.01	.08	.12
3 .00	15.639	40.1	24.1	.1	.09	1.02+03	1.04	.08	.12
3 15.00	15.888	40.7	24.4	.1	.09	1.03+03	1.06	.08	.12
3 30.00	15.763	40.8	24.5	.1	.09	1.03+03	1.06	.08	.12
3 45.00	15.329	40.7	24.4	.1	.09	1.03+03	1.06	.08	.12
4 .00	14.714	40.4	24.2	.1	.09	1.02+03	1.05	.08	.12
4 15.00	13.408	39.5	23.7	.1	.09	1.00+03	1.03	.08	.12
4 30.00	11.198	38.0	22.8	.1	.08	9.61+02	.99	.08	.11
4 45.00	8.918	36.0	21.6	.1	.08	9.11+02	.94	.07	.11
5 .00	7.070	33.9	20.3	.1	.07	8.58+02	.88	.07	.10
5 15.00	5.576	31.7	19.0	.1	.07	8.02+02	.82	.06	.10
5 30.00	4.365	29.5	17.7	.1	.06	7.46+02	.77	.06	.09
5 45.00	3.381	27.2	16.3	.1	.06	6.89+02	.71	.05	.08
6 .00	2.581	25.0	15.0	.1	.06	6.34+02	.65	.05	.08
6 15.00	1.936	23.0	13.8	.1	.05	5.81+02	.60	.05	.07
6 30.00	1.423	21.2	12.7	.1	.05	5.36+02	.55	.04	.06
6 45.00	1.024	20.2	12.1	.1	.04	5.10+02	.52	.04	.06
7 .00	.731	19.9	11.9	.1	.04	5.03+02	.52	.04	.06
7 15.00	.533	19.9	11.9	.1	.04	5.03+02	.52	.04	.06
7 30.00	.402	19.9	11.9	.1	.04	5.03+02	.52	.04	.06
7 45.00	.312	19.9	11.9	.1	.04	5.02+02	.52	.04	.06
8 .00	.248	19.8	11.9	.1	.04	5.02+02	.52	.04	.06
8 15.00	.201	19.8	11.9	.1	.04	5.02+02	.52	.04	.06
8 30.00	.165	19.8	11.9	.1	.04	5.02+02	.52	.04	.06
8 45.00	.138	19.8	11.9	.1	.04	5.01+02	.52	.04	.06
9 .00	.116	19.8	11.9	.1	.04	5.01+02	.52	.04	.06

FIG. VI-16

PETALUMA BASIN

QUALITY RESULTS AT CHANNEL 1010

Site Design/Management Control Simulations

The results of the simulations for all land use patterns clearly show that the urban areas are the major contributors to pollution during wet weather. It also dramatically shows that the growth management approach of varying population levels, locational and density factors, as reflected in the case of different alternatives, did not have a significant effect on the total washoff load in the basin.

As was described in the review of literature, there are a variety of site design/management controls that can be applied to reduce pollution from surface runoff. Three of these measures were simultated, using the Santa Rosa Centered 478 pattern, to determine their relative effectiveness against the growth management approach implied by the different land use alternatives. The three measures were: 1) street sweeping, 2) retention storage and 3) reduction of impervious surface coverage. The last two measures can be included in zoning ordinances.

Street Sweeping - It was mentioned earlier that all simulations were made assuming that 20 dry days preceded the storm. Since the Runoff-Quality Model assumes the buildup of pollutants increases in a linear fashion on a daily basis in urban areas, one technique for reducing urban washoff loads would be to sweep streets more frequently. Urban loads are computed on the basis of length of curbs and gutters. The easiest way to simulate this management alternative is to simply reduce the number of dry days preceding the storm to approximate more frequent street sweeping. To illustrate the effectiveness of street sweeping, a simulation was made assuming 10 dry days preceded the storm.

For purposes of simplicity, a 100% of sweeper efficiency was used in the simulation. However, rates of sweeping efficiency can vary greatly depending on such factors as method of street sweeping (manual, vacuum sweepers, vehichles sweepers), the type of vehicle sweeper, the pattern of sweeping (once over, twice over), roadway paving material, design of curb and gutter and type and size of the contaminant particle being swept. The EPA reports Water Pollution Aspects of Street Surface Contaminants (Sartor and Boyd, 1972) and Contributions of Urban Roadway Usage to Water Pollution (Shaheen, 1975) provide greater detail on both the nature of street contaminants and the efficiency issues of different street cleaning practices.

Retention Storage - Since the urban pollutant load is likely to be picked up early in the storm, a possible management technique would be to provide storage to capture a percentage of the initial urban runoff. The Runoff-Quality Model was programmed to do this and a simulation was made for the SRC-478 scenario in which the first 6 mm (.25 inches) of urban runoff was stored.

No specific facility was envisioned for this management technique since economic feasibility was not a consideration at this level of study. The purpose of simulating retention storage was to gain an insight into the potential for reducing the urban washoff load through

stormwater retention and disposal at a later time. One possible concept for accomplishing this would be a reservoir designed to store runoff up to some capacity after which excess runoff would be bypassed to the storm drainage system. The outlet of the reservoir could be connected to a sanitary sewer so that the reservoir could be drained after the storm to a treatment plant. The stormwater pollutant load would be treated and disposed along with sanitary flows.

Reduction of Percent Impervious Area - A simulation was made in which the percentage of impervious area associated with urban uses was reduced from those values used throughout the study. The purpose of this simulation was to determine what effect, if any, the reduction would have on runoff which would in turn effect washoff loads and channel qualities. The reduced percent impervious values compared to the original values are shown below:

Land Use Category	Original % Impervious Value	Reduced % Impervious Value
Low Density Residential	30	20
Medium Density Residential	65	40
High Density Residential	80	40
Commercial Centered	95	40
Commercial Suburban	90	40
Industrial	98	40

The reductions in percent impervious values shown above do not reflect actual reductions in paved areas and hard surfaces associated with urban land uses. They represent the "effective" percent of impervious area with respect to generating direct runoff. The reductions may be accomplished in a number of ways, most of which involve detention of urban stormwater runoff on the site where it originates. The following methods may be used to reduce runoff:

1. temporary ponding on ground surfaces;
2. temporary ponding on paved areas;
3. temporary ponding on roofs of buildings;
4. storage in permanent ponds having provision for variable depth;
5. treatment of groundwater surfaces to absorb and/or detain water;
6. routing of runoff to infiltration pits to both recharge groundwater supplies and reduce total flows to drainage systems;
7. collection of stormwater for supplementary water supplies; and
8. pervious pavement.

Fffectiveness of Site Design/Management Control Simulations. Table VI-7 presents the urban washoff for the Laguna Basin comparing street sweeping and retention storage to the original Santa Rosa Centered 478 simulation. (The reduction of the percent impervious factor effects urban washoff differently and will therefore be presented separately).

TABLE VI-7

EFFECTIVENESS OF SITE DESIGN/MANAGEMENT ALTERNATIVES
ON TOTAL URBAN WASHOFF

Watershed	Total Urban Washoff Load-TSS, Kilograms x 10^3 Original Simulation (SRC 478)	Street Sweeping	Retention Storage
Windsor Creek	13.4	6.7	3.4
Mark West Creek	15.1	7.6	4.1
Santa Rosa Creek	105.7	52.9	14.8
Laguna de Santa Rosa	81.6	40.8	6.8
Basin Total	215.8	108.0	29.1

The street sweeping alternative, due to the method of simulation, results in a washoff load of exactly one-half the original urban load since the number of dry days were halved. The retention storage alternative produces a dramatic decrease in the urban washoff load. For example, the washoff in Santa Rosa Creek, which is impacted by Santa Rosa, will reduce some 400% from 1973 conditions, when retention storage is used.

Table VI-8 shows the urban and rural washoff resulting from the reduced impervious coverage from each of the Laguna watersheds. It indicates only sightly lowered washoff loads from the Santa Rosa Centered 478 alternative which used the higher percent impervious values.

TABLE VI-8

REDUCED IMPERVIOUS AREA SIMULATION
WATERSHED WASHOFF LOADS

Watershed	Original SRC-478 Total Washoff-TSS, Kilograms x 10^3	Reduced Impervious Area
Windsor Creek	27.3	24.9
Mark West Creek	83.7	81.1
Santa Rosa Creek	154.0	145.4
Laguna de Santa Rosa	130.3	113.2
Total	395.3	364.6

The reductions in washoff loads shown in Table VI-8 are entirely the result of the reduction of washoff from rural subareas, adjacent to urban areas, which had less water runoff to erode the soil surface. The urban surface loading rates are based on the buildup of pollutants in curbs and gutters, which the model treats as a function of the area devoted to urban uses. Since the total areas devoted to urban uses were not reduced, the lengths of curbs and gutters remained the same and, consequently, the amount of urban loading available to runoff did not change. This model assumption is considered realistic in light of evidence provided by Contributions of Urban Roadway to Water Pollution that traffic-related contaminants and roadway surface material are the main components of street surface pollution buildups. Since neither of these two sources of contaminants would be greatly affected by the change of impervious surface conditions, it is felt preferable to keep the buildup loads constant. However, the exact numbers need to be viewed with some caution as some contaminants not associated with traffic-related activities or street surface materials, like pesticides or fecal coliform, might to absorbed or detained because of the increased pervious surface. This simulation did raise a question for further model refinement research. There has been little testing to determine how much of the pollutant (dust/dirt) accumulation in the street is due to street generated sources (rubber residue from tires, oil and grease, heavy metals, etc.) versus washoff from adjacent properties.

Table VI-9 and Figure VI-17 show the effects of the different site design/management control measures on the peak concentrations in various river channels. As before, both street sweeping and retention storage provide major improvements. Retention storage would again enable stream water to achieve a quality far higher than that of the present. However, the reduction in impervious area coverage could well have a negative impact of major proportions. The reduced runoff, the same urban washoff load and a slightly reduced rural washoff load resulted in increases in the concentrations of total suspended solids in channels draining urban areas. The water that is retained by the new pervious area reduces the amount of water available for diluting the pollutants which are washed off thereby resulting in the higher concentrations. Table VI-10 indicates the reduction in peak flow when the new impervious surface coverage standards are used.

This rather startling finding has a number of implications. First, a number of zoning and subdivision approaches have been designed to reduce the impervious area coverage through requirements for greater amounts of open space per development. Secondly, the decreased impervious surface approach can be applied to solve a variety of planning issues including groundwater recharge, reduce flood potential and hopefully reduce pollution. Therefore, there is real potential for conflicting impacts from such a design approach. Unless it can be combined with retention storage, street sweeping or other means of eliminating the pollutants, the reduced impervious area approach can be counter productive.

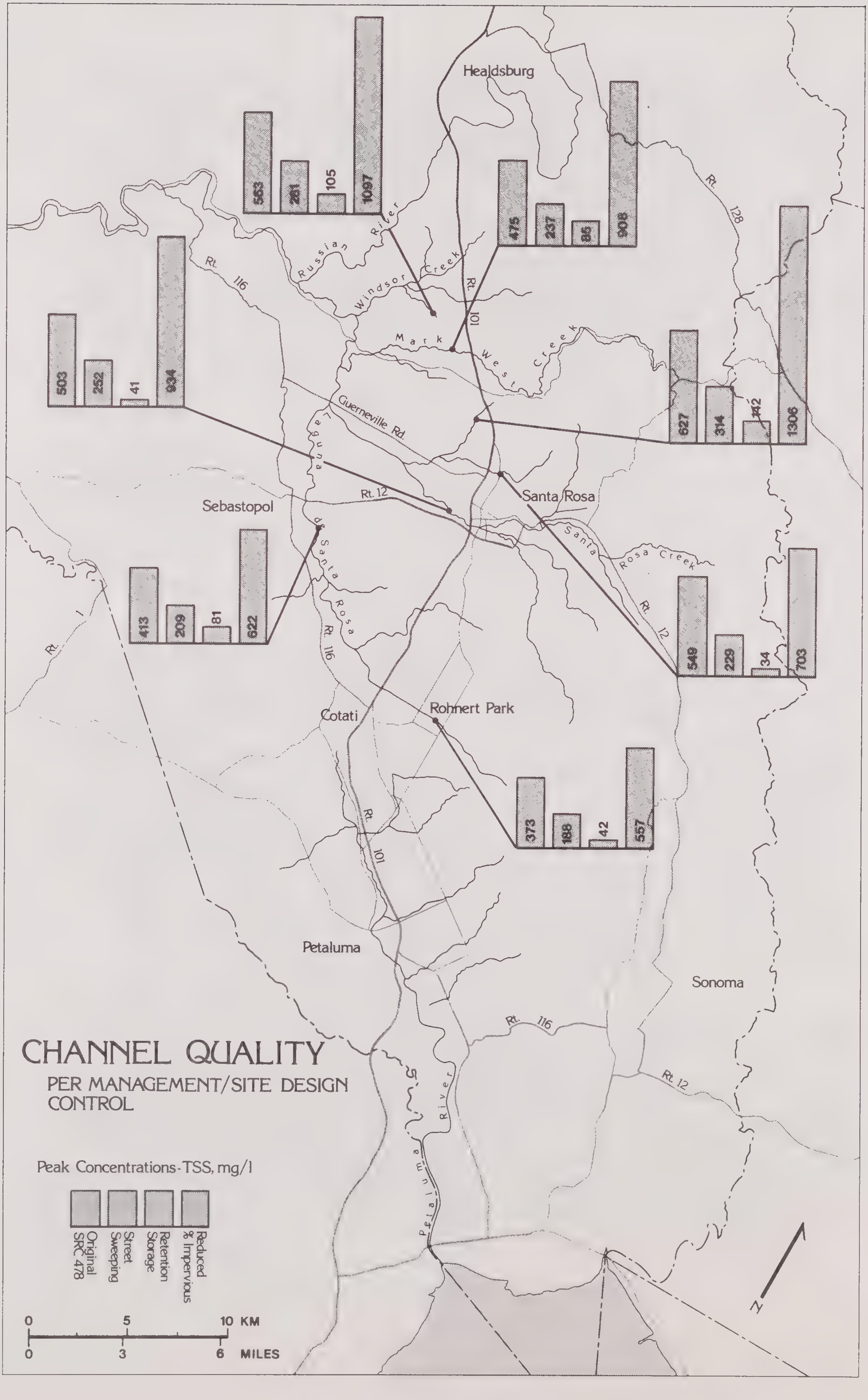

Healdsburg
563
281
105
1097
475
237
85
908
503
252
41
934
627
314
142
1306
413
209
81
622
549
229
34
703
373
188
42
557
Russian River
Windsor Creek
Mark West Creek
Rt. 116
Rt. 101
Rt. 128
Guerneville Rd.
Laguna de Santa Rosa
Rt. 12
Sebastopol
Santa Rosa
Santa Rosa Creek
Rt. 1
Cotati
Rohnert Park
Petaluma
Sonoma
Petaluma River
N
CHANNEL QUALITY
PER MANAGEMENT/SITE DESIGN CONTROL
Peak Concentrations-TSS, mg/l
Original SRC 478
Street Sweeping
Retention Storage
Reduced % Impervious
0
5
10 KM
0
3
6 MILES

FIG. VI-17

TABLE VI-9

EFFECTIVENESS OF SITE DESIGN/MANAGEMENT ALTERNATIVES
ON PEAK CONCENTRATIONS, TSS, mg/1

Watershed/Channel	Original Simulation (SRC 478)	Street Sweeping	Retention Storage	Reduced Impervious Area
Windsor Creek				
Channel 1002	563	281	105	1097
Mark West Creek				
Channel 2002	475	237	85	908
Santa Rosa Creek				
Channel 3002	503	252	41	934
3004	549	229	34	703
3005	627	314	142	1306
3007	359	180	43	531
3008	318	160	50	451
3011	355	178	37	498
Laguna de Santa Rosa				
Channel 4004	413	209	81	622
4005	161	90	72	180
4007	452	226	37	725
4012	373	188	42	557

Groundwater Impacts

The previous discussion concerns the impacts of development on surface water quality. Groundwater supplies can also be impacted by urbanization in terms of both quantity and quality.

There are three primary problem areas associated with urbanization which could lead to a degradation of groundwater quality in Sonoma County. First, urbanization can reduce the areas of natural groundwater recharge. This would result from replacement of open, highly pervious areas which serve to recharge the groundwater basin with the impervious surfaces of development. A reduction of natural recharge would lead to lowering of the groundwater table and a corresponding degradation in the mineral quality (total dissolved solids) of the groundwater. The degradation of quality in this case would result from concentrating the basin salt load in a smaller volume of groundwater.

TABLE VI-10

WATER RUNOFF FROM REDUCED IMPERVIOUS COVERAGE
PEAK RUNOFF, m^3/sec

Watershed/Channel	Peak Runoff, m^3/sec Original (SRC 478)	Reduced % Impervious Area
<u>Windsor Creek Watershed</u>		
Channel 1002	6.8	3.5
<u>Mark West Creek Watershed</u>		
Channel 2002	80.0	78
<u>Santa Rosa Creek Watershed</u>		
Channel 3002	88.4	78.6
3005	11.8	7.3
<u>Laguna de Santa Rosa Watershed</u>		
Channel 4004	32.3	22.6
4009	14.1	10.7

Secondly, the salt load to the groundwater basin could increase as open areas are urbanized depending on the use made of the open areas prior to development. Application of fertilizer to lawns in areas that were previously fallow and unused would tend to increase the total salt load available for infiltrating the underlying groundwater basin.

Third, groundwater problems can arise through the use of septic tanks in areas with unsuitable soil characteristics for septic tank leach fields. The Rural Dispersed alternative anticipates the further development of very low density residential areas such as three-acre ranchettes. Sparse development results in very high unit costs of sewering and the potential demand for septic tank use for wastewater disposal.

While the scope of this study did not permit a detailed quantitative analysis of impacts on groundwater quality, land use information from the preprocessor together with a map of the recharge areas can be used to illustrate the potential impacts of the alternatives on groundwater. Figures 19 through 21 show the percentage of land devoted to urban uses in the Base Year case and Santa Rosa Centered 478, superimposed

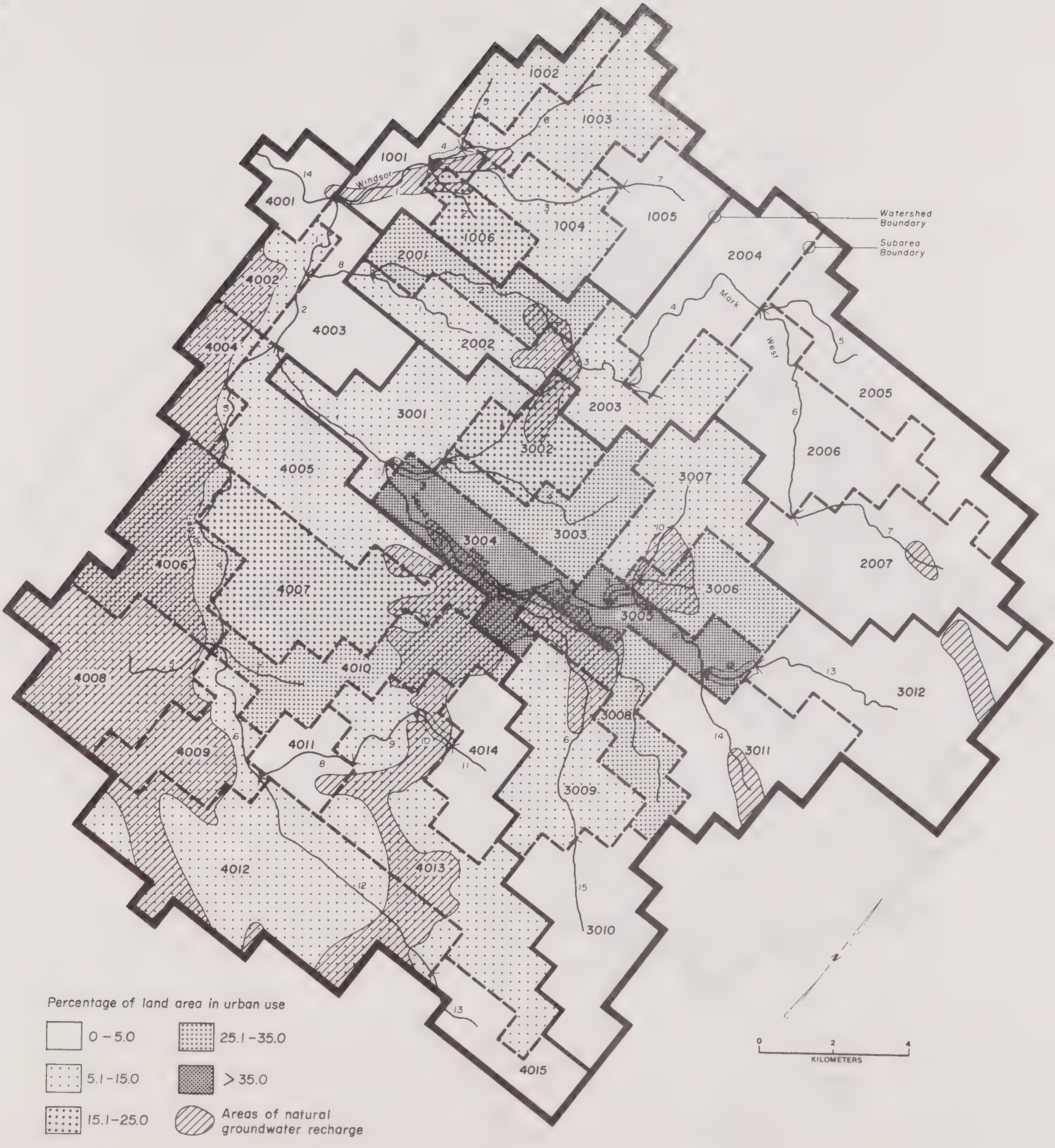


FIG. VI-18

LAGUNA BASIN - BASE YEAR

URBANIZATION AND GROUNDWATER RECHARGE AREAS

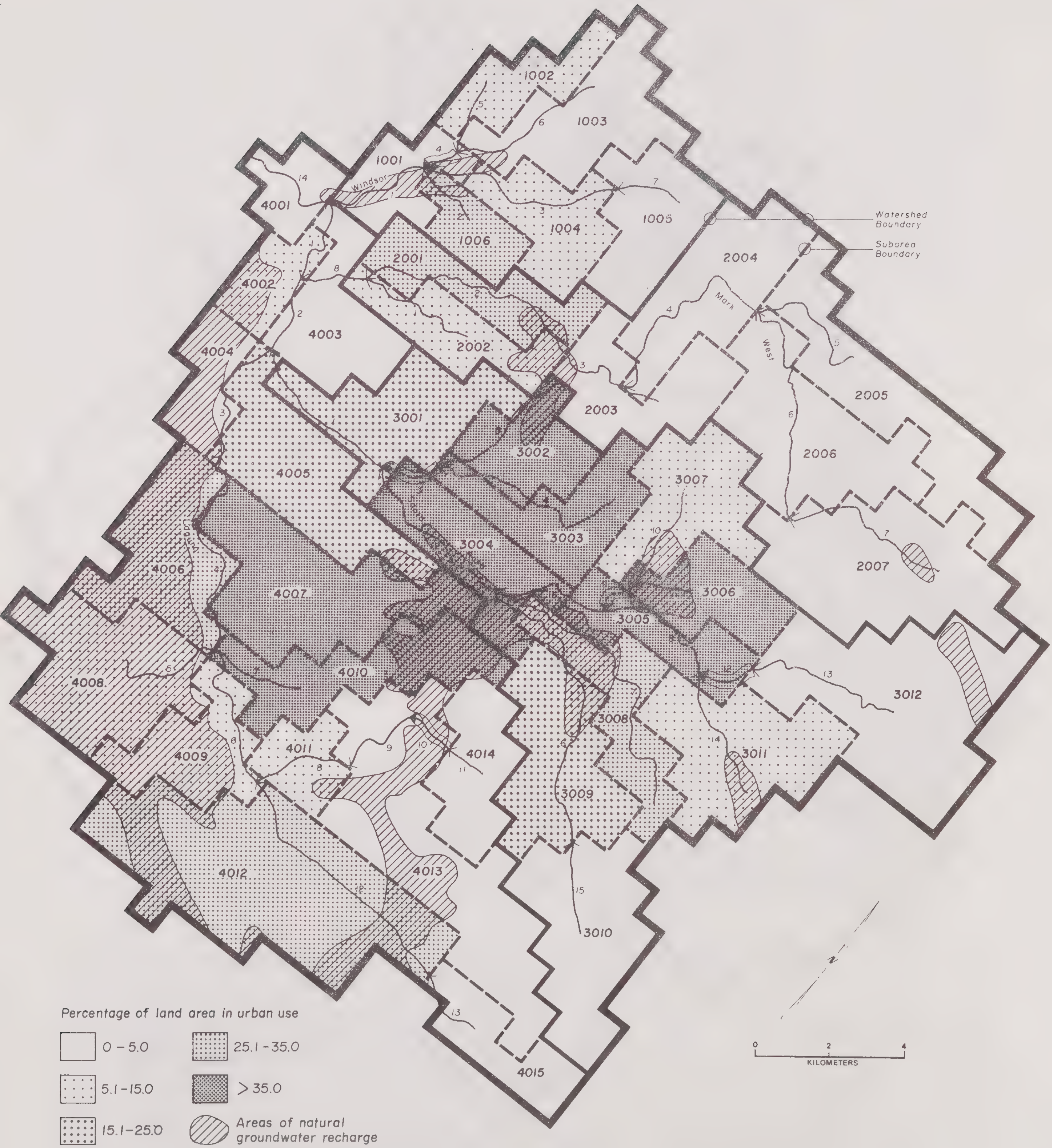


FIG. VI–19

LAGUNA BASIN - SRC-478

URBANIZATION AND GROUNDWATER RECHARGE AREAS

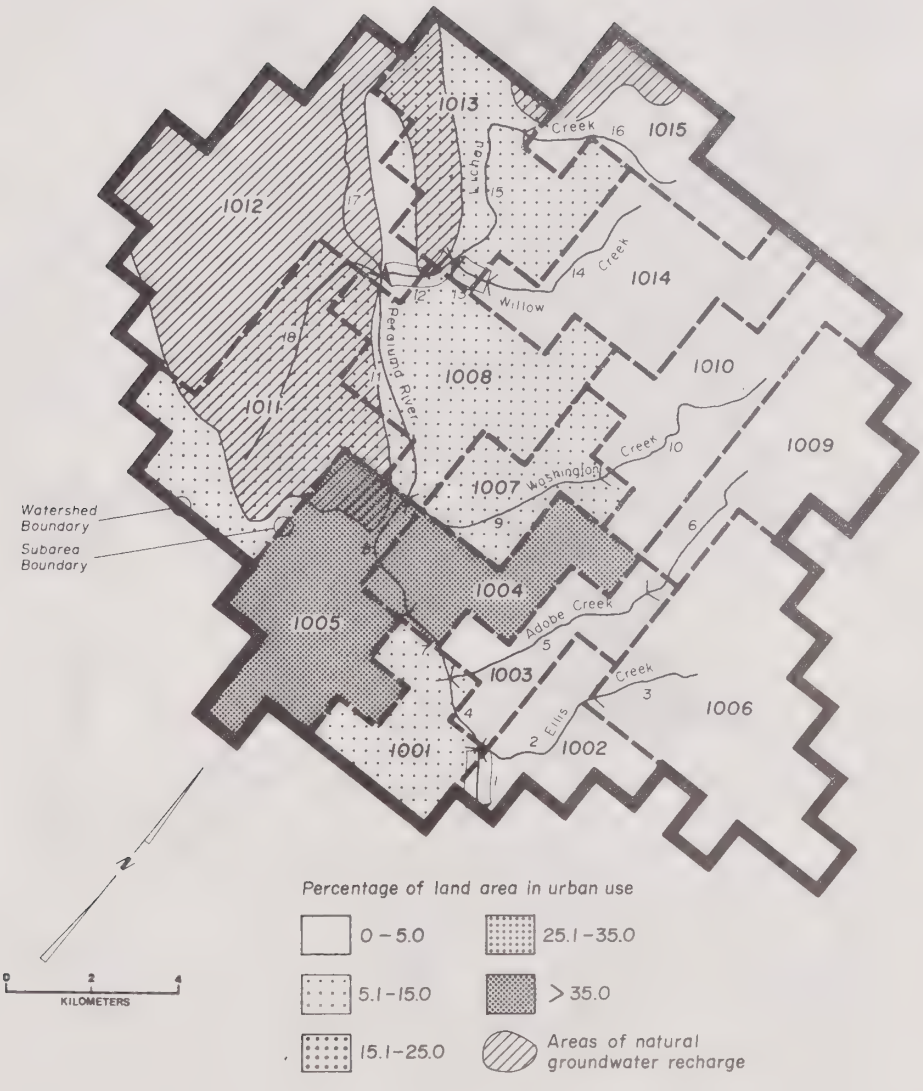


FIG. VI-20

PETALUMA BASIN - BASE YEAR

URBANIZATION AND GROUNDWATER RECHARGE AREAS

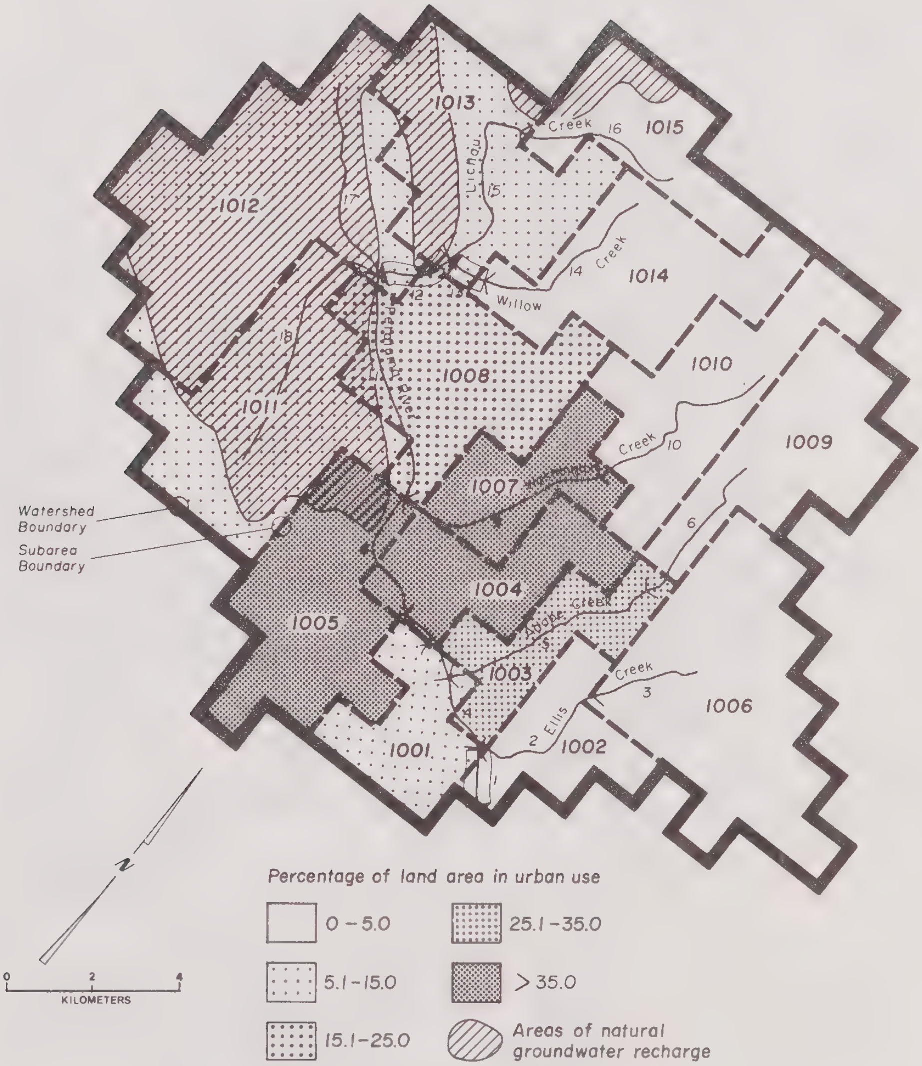


FIG. VI–21

PETALUMA BASIN - SRC-478

URBANIZATION AND GROUNDWATER RECHARGE AREAS

on the areas of natural groundwater recharge in the Laguna and Petaluma Basins. By comparing Base Year to Santa Rosa Centered 478, it can be seen that the percentage of impervious areas in several subareas around Santa Rosa will increase due to urbanization. Such increases will reduce the ability of the affected recharge areas to maintain existing water levels in the underlying groundwater basins. On the other hand, the recharge areas in the Sebastopol, Rohnert Park and Cotati areas will not be developed by the Urban Centered or Continuing Trends alternatives. In the Petaluma Basin, the primary recharge areas are northwest of the City of Petaluma. Land use patterns concentrating growth by increasing densities in existing urban areas would tend to have less impact on recharge areas than the patterns that disperse growth.

A recent report by the Department of Water Resources discusses groundwater problems in Sonoma County associated with septic tanks. The report concludes that most of the rural areas in Sonoma County are unsuitable for the construction and operation of septic tank and leach field systems. The soils of Sonoma County are all classified as unacceptable with the exception of small areas around Santa Rosa, north of Santa Rosa and Petaluma. The above mentioned exceptions are considered generally to have permeability constraints and the report recommends that on-site testing must be done to demonstrate that soil characteristics are indeed acceptable. Land use alternatives involving scattered low density residential development are going to present greater problems of how to provide economical sewerage services than those scenarios which tend to concentrate urban development.

AIR QUALITY ANALYSIS

The air quality results of the study highlighted a number of growth management issues which pose some contradictory planning considerations. Higher population levels and more concentrated population and employment patterns result in higher localized air pollution concentrations of carbon monoxide and particulates. Yet, an alternative -- lower population levels and a more dispersed development pattern -- would make it more difficult to support a public transportation program, thereby continuing the reliance on the private automobile. (Such a development pattern can also have other negative impacts including increasing the cost of municipal services or reducing the quantity of valuable agriculture land.) Finally, a population pattern that distributes population and employment more evenly throughout the County could provide the "worst case" alternative for oxidant due to conditions that may exist outside the control of Sonoma County officials.

The Urban Centered alternative presents Petaluma and the City of Sonoma with high levels of oxidant because of both increased population in the cities and oxidant transport from other sections of the Bay Area. The air quality results are described in two sections: non-reactive pollutants (i.e., carbon monoxide, particulates) and oxidant. The discussion on carbon monoxide focuses on the importance of auto emission devices and an inspection and maintenance program.

General Considerations

While extensive air monitoring activities have been conducted by the BAAPCD in the Bay Area for many years, the air quality measurements in the study area are limited. In Sonoma County, measurements are taken on a routine and complete basis at three sites -- Santa Rosa, Petaluma and Sonoma. Measurements from these locations are of value in monitoring current air quality in cities considered to have the highest air pollution levels. However, because they do not provide any information on the variability of air quality throughout the County an air pollutant dispersion model was used to provide an projection of future air quality. The simulation model is based both on theoretical considerations and actual measurements in the atmosphere, which approximate the extent to which pollutants are diluted by mixing with the air as they travel with the wind from the pollutant source (smoke stack, automobile, etc.) to any site where the air quality is to be determined. (Such a modeling effort was not used for oxidant analysis). Because the dispersion model estimates are directly related to the source configuration of a given land use pattern and because the estimates can be made at many points throughout a given study area, the spatial variability of air quality may thereby be assessed for a variety of future land use patterns.

In the application of dispersion modeling to the problem of air quality estimation, the modeling results themselves are considered only as a tool to aid the air quality analyst in drawing meaningful conclusions with the results subject to interpretation. The accuracy of modeling results varies greatly with the pollutant of concern, the type of model and the quality of information regarding source emissions and meteorology.

Compiling an Emissions Inventory. A detailed emissions inventory was made to ensure the highest possible degree of validity. The inventory was made for four of the pollutants for which federal ambient air quality standards have been promulgated: carbon monoxide, non-methane hydrocarbon, sulfur dioxide and particulate. To provide a maximum of spatial detail within reasonable limits, an estimate was made of the rate of emission of each pollutant in each study grid cell covering the currently and potentially urbanized portions of Sonoma County from Healdsburg to the southern County boundary and from Sebastopol eastward to Sonoma.

In each of the grid squares for which an emission rate was computed, emissions from five separate source categories were summed to provide a total emission from the square:

1) Emissions from motor vehicles were computed for portions of motor vehicle trips identified as occurring within each grid square;

2) Emissions from stationary sources such as industrial sites with identifiable locations were assigned to the grid square containing their locations;

3) Emissions from airports were assigned uniformly to the grid squares containing the boundaries of ground-based aircraft activity;

4) Emissions from agricultural activity were assigned to grid squares within which polluting agricultural activity such as burning is presumed to occur;

5) Emissions from stationary sources for which specific locations cannot be determined were distributed proportional to population among the grid squares.

Meteorological and Climatological Considerations. The model used for non-reactive pollutants requires: 1) knowledge of wind speed and direction characteristics in the study area and over the nine county region as a whole and 2) information on the characteristics of the temperature inversion and information on atmospheric stability or the ability of the atmosphere to dilute pollutants by mixing. Details of the incorporation of this information in the dispersion model are presented in Appendix B.

Model Calibration. The non-reactive modeling system, as explained in Chapter V and outlined in Appendix C, is a combination of the "gaussian plume" and lognormal statistical formulae. An annual average value for a pollutant concentration is obtained for each grid square using a gaussian plume dispersion model in conjunction with the emissions inventory associated with a given land use distribution (e.g., Continuing Trends 478). Estimates of the frequency with which air quality standards are exceeded are then obtained statistically on the basis of historical air monitoring information. This modeling procedure is strictly applicable only to those pollutants such as carbon monoxide that are not subject to significant chemical transformation or physical removal within the study area. Other pollutants may be analyzed with due consideration for the limitations of the modeling technique.

First, the simulation model was calibrated using observed air quality. In the case of this study, an analysis was done in the study area for Base Year (1973) and results compared with 1973 air quality data at the Santa Rosa air monitoring station. Data from years other than 1973 at Santa Rosa and Petaluma were also considered. Modeling results for carbon monoxide in this study as well as in studies conducted in other areas of the Bay Area Air Pollution Control District's jurisdiction support the validity of the modeling approach. These results are within 20% of measured station values for the annual average. Suspended particulate modeling has proven similarly successful. Non-methane hydrocarbon results are usually less satisfactory, due in part to the reactive nature of the pollutant and a greater uncertainty in the rate of emission and source distribution. Sulfur oxide estimates by this model are not directly comparable to station values because such measurements are not available in Sonoma County. To reduce all pollutant estimates to a common basis for comparison of land use alternatives, Base Year estimates in all grid squares are given a constant adjustment based upon the difference between model

estimates and observed levels in the grid squares containing the monitoring stations. The model was thus calibrated in the monitored grid squares to the Base Year values with the assumption that such calibration will remain valid in future years and throughout the study area.

Interpretation of Modeling Results

Both theoretically and on the basis of direct comparison with observation, the results of the carbon monoxide analysis are the most accurate. Carbon monoxide concentrations are related almost exclusively to the use of the automobile and vary directly with the density of vehicle travel and inversely with vehicle speed. For this reason, the distribution of carbon monoxide concentrations associated with alternative plan strategies is a good indicator of the relative effect of transportation alternatives or the lack thereof upon the air pollution problem. By estimating carbon monoxide pollution with and without auto emission control devices for the same growth alternative, as is done in this study, the importance of motor vehicle pollution control is graphically revealed.

Particulate pollution on the other hand is an excellent indicator of non-vehicular, population-related pollution because it is primarily associated with a wide range of industrial, commercial, construction and other human activities essentially unrelated to the use of the automobile. Because technological and regulatory control of particulate sources has fairly well reached its limit in the Bay Area, particulate pollution estimates are good indicators of the air quality impact of general population growth and alternative population density configurations.

Sulfur dioxide pollution is an indicator of the impact of industrial activity which accounts for the bulk of sulfur oxide emissions. Generally speaking, sulfur dioxide pollution in Sonoma County is negligible at present due to a minimal industrial base. Locally impacted areas, however, are readily identified from the analysis, and the effect of projected increases in the use of fossil fuels is evident. (As a point of interest, the geysers in northern Sonoma County, located outside the study area, are another source of sulfur dioxide.)

Impacts of Development on the Emission of Carbon Monoxide

Comparison among land use alternatives is made in two ways: (1) direct observation from the isopleth maps of which areas are most greatly affected by pollution and (2) using a system of ranking on the basis of frequency of violations of the Federal CO standard.

Figure VI-22 shows the modeling estimate of carbon monoxide (CO) annual average concentration distribution for Base Year (1973) throughout the study area. The model was calibrated by increasing

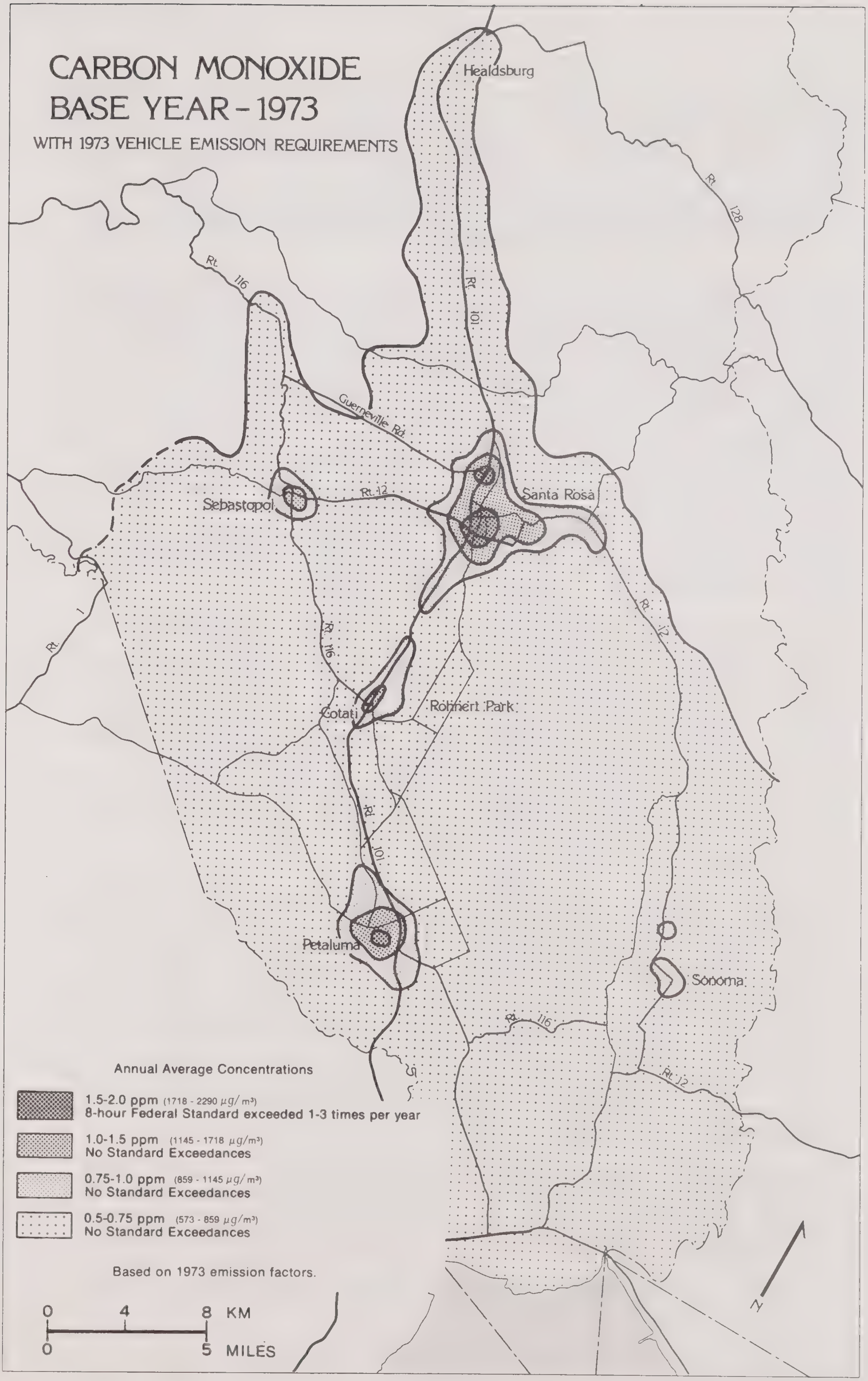

CARBON MONOXIDE
BASE YEAR - 1973
WITH 1973 VEHICLE EMISSION REQUIREMENTS
Healdsburg
Rt. 128
Rt. 116
Rt. 101
Guerneville Rd.
Santa Rosa
Sebastopol
Rt. 12
Rt. 1
Rt. 116
Cotati
Rohnert Park
Rt. 101
Petaluma
Sonoma
Rt. 116
Rt. 12
Annual Average Concentrations
1.5-2.0 ppm (1718 - 2290 μg/m³)
8-hour Federal Standard exceeded 1-3 times per year
1.0-1.5 ppm (1145 - 1718 μg/m³)
No Standard Exceedances
0.75-1.0 ppm (859 - 1145 μg/m³)
No Standard Exceedances
0.5-0.75 ppm (573 - 859 μg/m³)
No Standard Exceedances
Based on 1973 emission factors.
0 4 8 KM
0 5 MILES
N

FIG. VI-22

predicted concentrations by 20 percent to provide Base Year agreement with air monitoring data. The figure indicates an estimated non-urban background concentration of between 573 and 859 micrograms per cubic meter of air ($\mu g/m^3$) or 0.5 and 0.75 parts per million (ppm). This background results from emissions in Sonoma County as well as from emissions outside the County. It is estimated that only some 229 $\mu g/m^3$ of CO as an annual average is derived from outside the County.

In the urban areas where highest vehicle trips and reduced vehicle speeds create high densities of CO emissions, levels of carbon monoxide are considerably elevated above the non-urban background. Occassional violations of the primary 8-hour Federal standard for carbon monoxide are projected for the Santa Rosa and Petaluma areas. No violations are observed or projected predicted for the 1-hour CO standard. The significance of the findings on carbon monoxide is that the emissions are almost exclusively related to the distribution and density of motor vehicle activity. The carbon monoxide problem is therefore an indicator of the impact of the automobile on the quality of the air. Mitigation of carbon monoxide pollution may therefore be accomplished either by technological control of motor vehicle emissions or by regulating the extent and distribution of vehicular activity to decrease the density of motor vehicle emissions.

The projected carbon monoxide annual average concentrations for all growth alternatives dropped substantially from their 1973 level. They were below the 1973 level for all cities at both the 478,000 and 630,000 county population levels. The reason for this drop was the assumed full and effective implementation of both the stationary source controls as envisioned and the currently promulgated Federal Motor Vehicle Emission Control Program. The projected impact of vehicle control devices (catalytic converters, etc.) is anticipated to offset any increases in vehicular activity so that no violations of carbon monoxide air quality standards are projected for the county regardless of the land use alternative.

However, as noted in Table VI-11, each urban area will be affected to differing degrees depending upon the scenario. The most consistently low land use alternatives in terms of annual average and maximum concentrations are Rural Dispersed, Continuing Trends and Suburban Dispersed for the 478,000 population level. On the other hand, Santa Rosa in the Santa Centered 630 alternative, with the combination of the highest population and employment and the greatest land use densities, will have the highest CO concentrations. Similarly, all other cities have their highest CO counts in the Urban Centered 630 alternative, which gives them also the largest and most concentrated population and employment pattern.

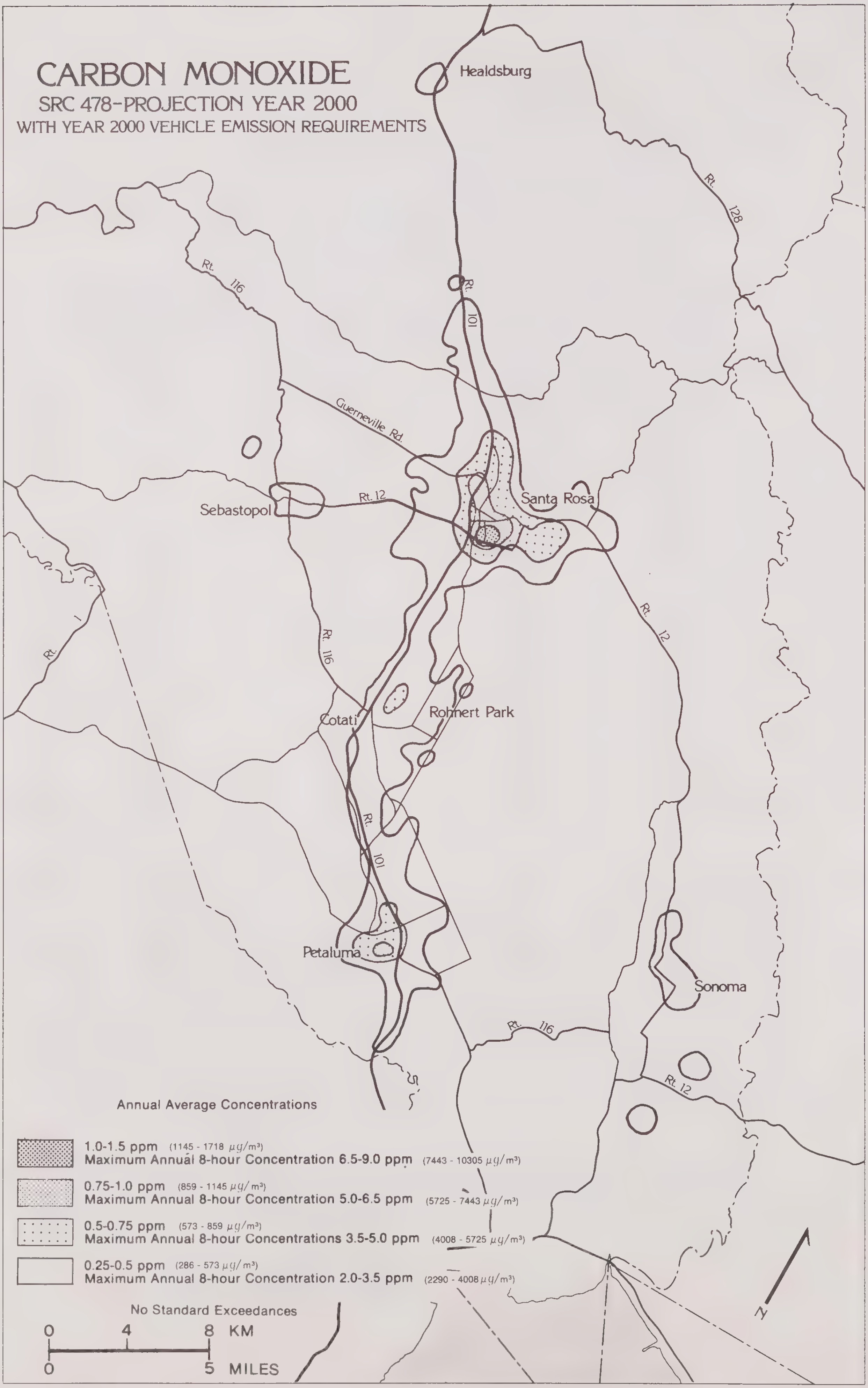
Figures VI-23 through VI-26 are the isopleth maps for some of the growth patterns. (Because the alternatives shown in the figures indicate the full range of pattern variations, not all nine alternatives are diagramed.) A number of conditions are apparent from the maps:

1) the downtown or commercial areas of all cities have the highest concentrations;

Table VI-11

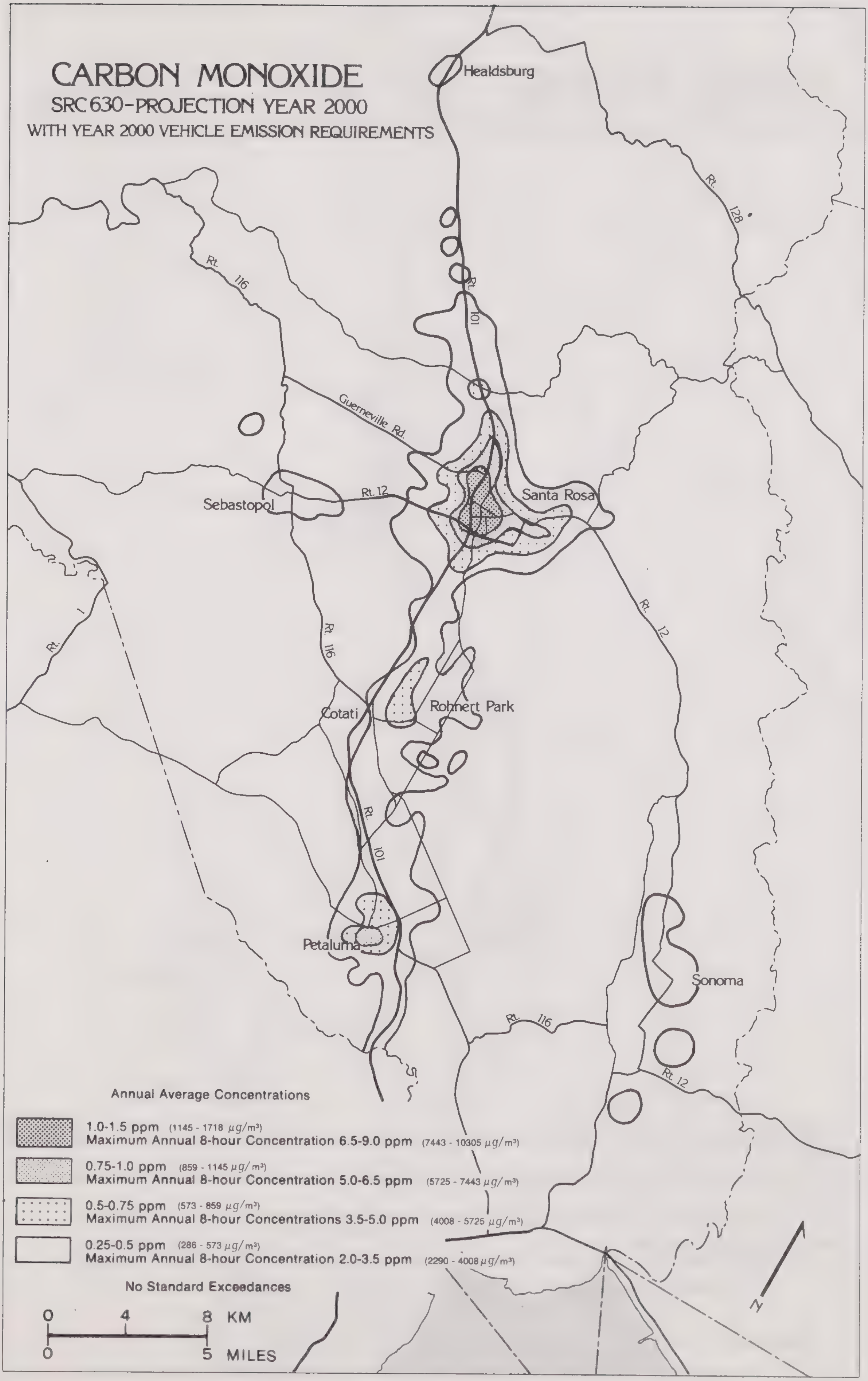
ANNUAL AVERAGE AND MAXIMUM ANTICIPATED CONCENTRATION FOR CARBON MONOXIDE ($\mu g/m^3$)

LAND-USE ALTERNATIVE			SANTA ROSA	ROHNERT PARK-COTATI	SONOMA	PETALUMA
SRC	478	An. Avg.	1260	698	573	1214
		An. Max.	8015	4580	3435	8015
SRC	630	An. Avg.	1580	847	561	1237
		An. Max.	10305	5725	3435	8015
UC	478	An. Avg.	927	607	698	1305
		An. Max.	5725	4580	4580	8015
UC	630	An. Avg.	1088	802	859	1431
		An. Max.	6870	5725	5725	9160
SD	478	An. Avg.	1168	721	504	1145
		An. Max.	6870	4580	3435	6870
SD	630	An. Avg.	1318	779	550	1156
		An. Max.	8015	5725	3435	6870
RD	478	An. Avg.	1099	687	573	1202
		An. Max.	5725	4580	3435	8015
CT	478	An. Avg.	962	664	595	1111
		An. Max.	5725	4580	3435	6870
BY		An. Avg.	2313	1191	1099	1969
		An. Max.	13740	8015	5725	17595



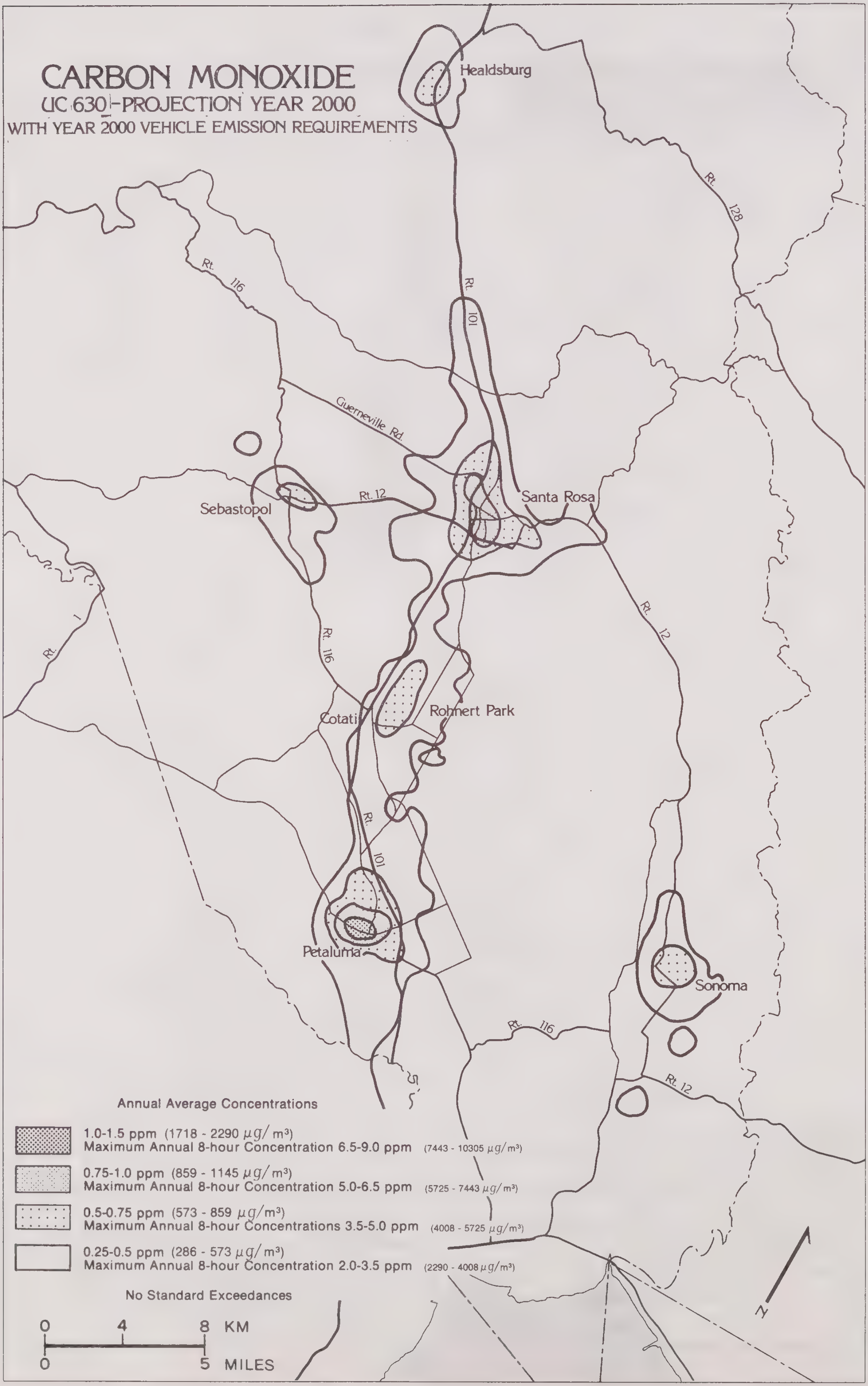
CARBON MONOXIDE
SRC 478-PROJECTION YEAR 2000
WITH YEAR 2000 VEHICLE EMISSION REQUIREMENTS
Healdsburg
Rt. 128
Rt. 116
Rt. 101
Guerneville Rd.
Rt. 12
Sebastopol
Santa Rosa
Rt. 12
Rt. 1
Rt. 116
Cotati
Rohnert Park
Rt. 101
Petaluma
Sonoma
Rt. 116
Rt. 12
Annual Average Concentrations
1.0-1.5 ppm (1145 - 1718 μg/m³)
Maximum Annual 8-hour Concentration 6.5-9.0 ppm (7443 - 10305 μg/m³)
0.75-1.0 ppm (859 - 1145 μg/m³)
Maximum Annual 8-hour Concentration 5.0-6.5 ppm (5725 - 7443 μg/m³)
0.5-0.75 ppm (573 - 859 μg/m³)
Maximum Annual 8-hour Concentrations 3.5-5.0 ppm (4008 - 5725 μg/m³)
0.25-0.5 ppm (286 - 573 μg/m³)
Maximum Annual 8-hour Concentration 2.0-3.5 ppm (2290 - 4008 μg/m³)
No Standard Exceedances
0 4 8 KM
0 5 MILES
N

FIG. VI-23



CARBON MONOXIDE
SRC630-PROJECTION YEAR 2000
WITH YEAR 2000 VEHICLE EMISSION REQUIREMENTS
Healdsburg
Rt. 128
Rt. 116
Rt. 101
Guerneville Rd.
Sebastopol
Rt. 12
Santa Rosa
Rt. 1
Rt. 116
Rt. 12
Cotati
Rohnert Park
Rt. 101
Petaluma
Sonoma
Rt. 116
Rt. 12
Annual Average Concentrations
1.0-1.5 ppm (1145 - 1718 μg/m³)
Maximum Annual 8-hour Concentration 6.5-9.0 ppm (7443 - 10305 μg/m³)
0.75-1.0 ppm (859 - 1145 μg/m³)
Maximum Annual 8-hour Concentration 5.0-6.5 ppm (5725 - 7443 μg/m³)
0.5-0.75 ppm (573 - 859 μg/m³)
Maximum Annual 8-hour Concentrations 3.5-5.0 ppm (4008 - 5725 μg/m³)
0.25-0.5 ppm (286 - 573 μg/m³)
Maximum Annual 8-hour Concentration 2.0-3.5 ppm (2290 - 4008 μg/m³)
No Standard Exceedances
0 4 8 KM
0 5 MILES
N

FIG. VI-24



CARBON MONOXIDE
UC 630 - PROJECTION YEAR 2000
WITH YEAR 2000 VEHICLE EMISSION REQUIREMENTS
Healdsburg
Rt. 128
Rt. 116
Rt. 101
Guerneville Rd.
Rt. 12
Sebastopol
Santa Rosa
Rt. 12
Rt. 116
Rt. 1
Cotati
Rohnert Park
Rt. 101
Petaluma
Sonoma
Rt. 116
Rt. 12
Annual Average Concentrations
1.0-1.5 ppm (1718 - 2290 μg/m³)
Maximum Annual 8-hour Concentration 6.5-9.0 ppm (7443 - 10305 μg/m³)
0.75-1.0 ppm (859 - 1145 μg/m³)
Maximum Annual 8-hour Concentration 5.0-6.5 ppm (5725 - 7443 μg/m³)
0.5-0.75 ppm (573 - 859 μg/m³)
Maximum Annual 8-hour Concentrations 3.5-5.0 ppm (4008 - 5725 μg/m³)
0.25-0.5 ppm (286 - 573 μg/m³)
Maximum Annual 8-hour Concentration 2.0-3.5 ppm (2290 - 4008 μg/m³)
No Standard Exceedances
0 4 8 KM
0 5 MILES
N

FIG VI-25

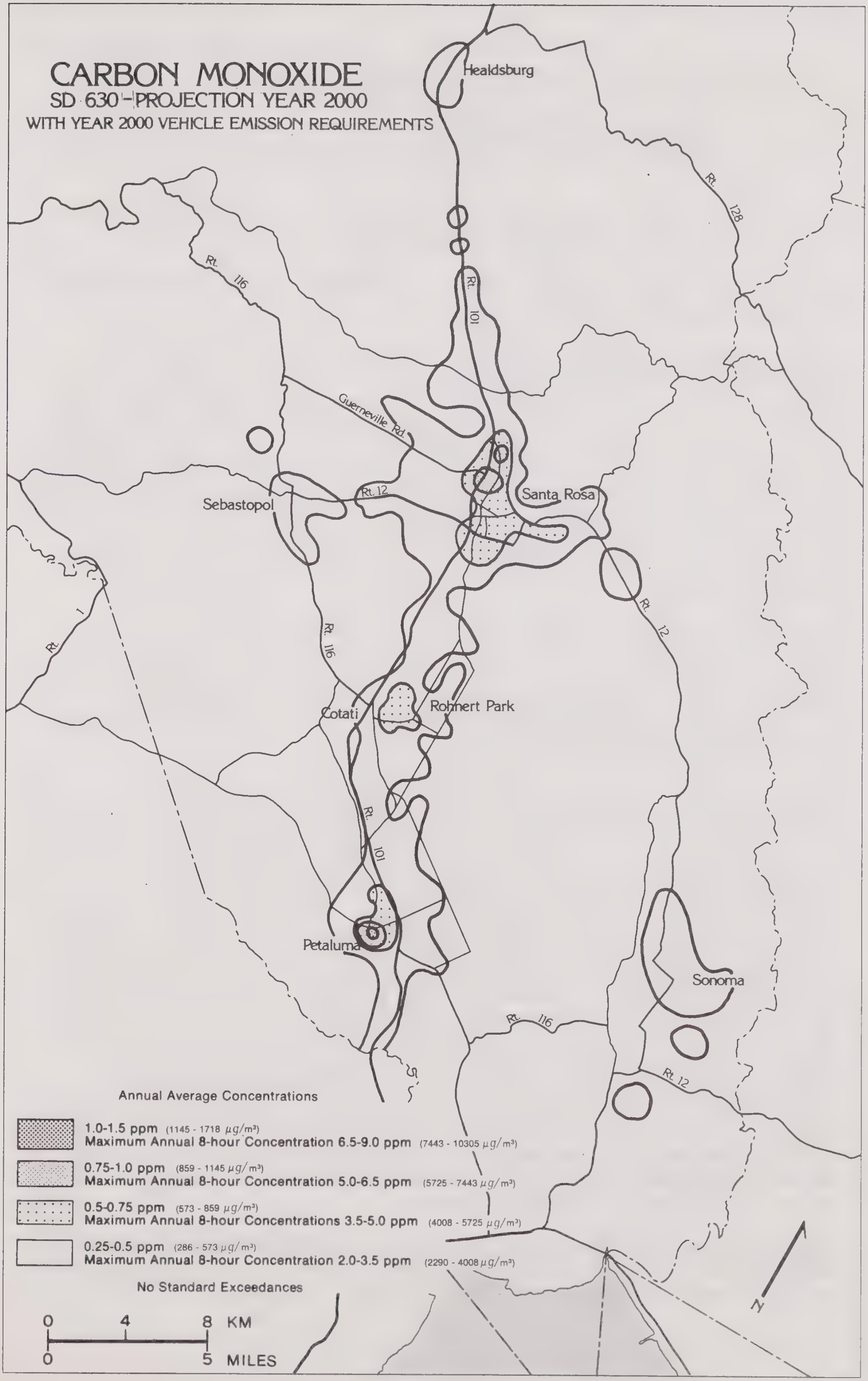

CARBON MONOXIDE
SD 630 - PROJECTION YEAR 2000
WITH YEAR 2000 VEHICLE EMISSION REQUIREMENTS
Healdsburg
Rt. 128
Rt. 116
Rt. 101
Gurneville Rd.
Sebastopol
Rt. 12
Santa Rosa
Rt. 1
Rt. 116
Rt. 12
Cotati
Rohnert Park
Rt. 101
Petaluma
Sonoma
Rt. 116
Rt. 12
Annual Average Concentrations
1.0-1.5 ppm (1145 - 1718 μg/m³)
Maximum Annual 8-hour Concentration 6.5-9.0 ppm (7443 - 10305 μg/m³)
0.75-1.0 ppm (859 - 1145 μg/m³)
Maximum Annual 8-hour Concentration 5.0-6.5 ppm (5725 - 7443 μg/m³)
0.5-0.75 ppm (573 - 859 μg/m³)
Maximum Annual 8-hour Concentrations 3.5-5.0 ppm (4008 - 5725 μg/m³)
0.25-0.5 ppm (286 - 573 μg/m³)
Maximum Annual 8-hour Concentration 2.0-3.5 ppm (2290 - 4008 μg/m³)
No Standard Exceedances
0 4 8 KM
0 5 MILES
N

FIG. VI-26

2) the CO pattern follows the roadway pattern;

3) the more dispersed population patterns, such as Suburban Dispersed 630, has the greatest spread of CO for Santa Rosa; and

4) the meteorlogical patterns do not have a substantial effect in dispersing the CO concentrations.

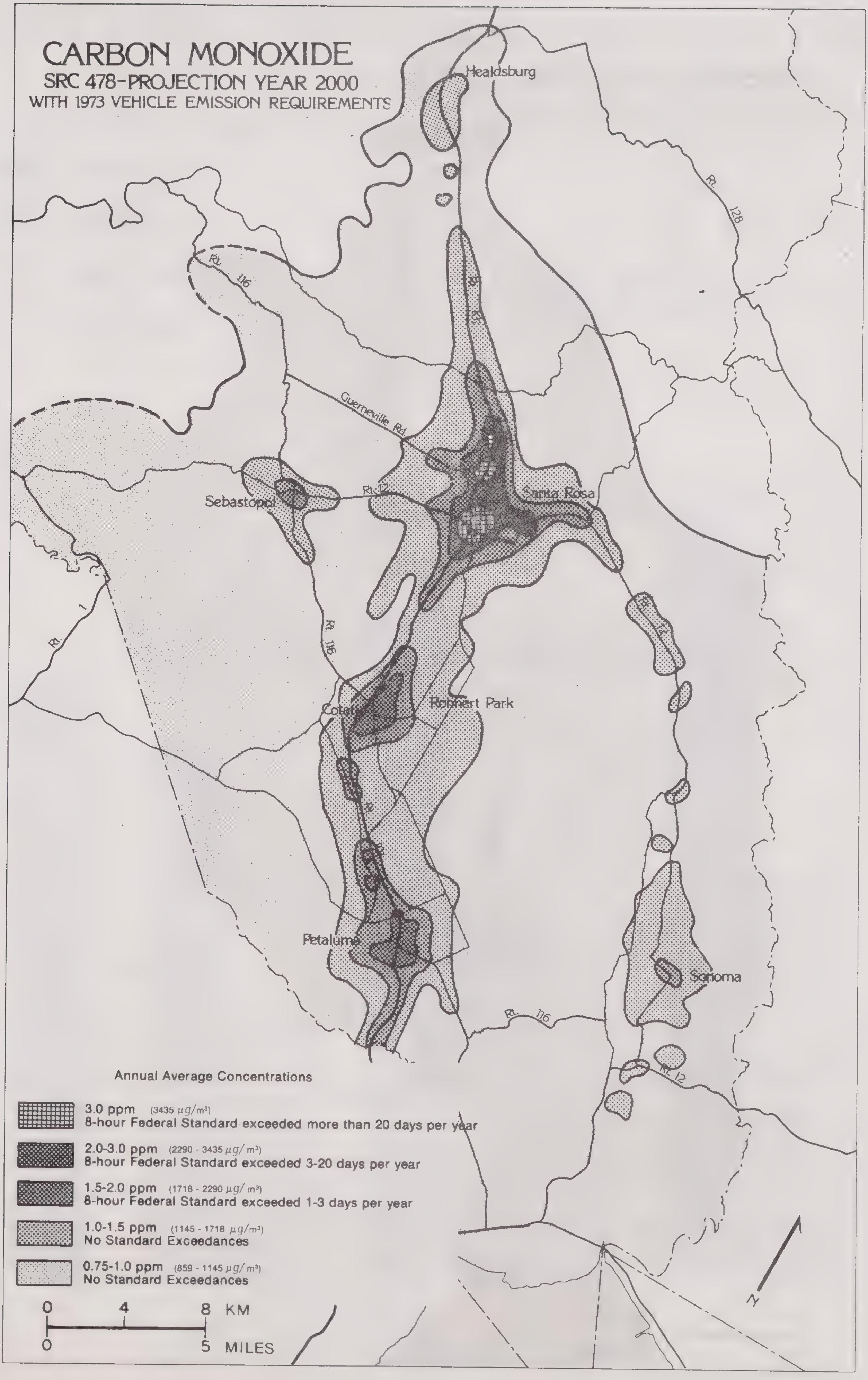
All of these findings simply verify the impact of motor vehicle travel on carbon monoxide problems.

Vehicle Emission Controls. Figure VI-27 and VI-28 illustrate the critical role of vehicle emission controls in offsetting the effect of growth on carbon monoxide pollution. The analysis illustrated by the figures is the CO levels for Continuing Trends 478,000 using the 1973 vehicle emission factors. This situation is equivalent to a complete breakdown of the motor vehicle emission control program beyond 1973 including no further improvements in the emission control devices and elimination of the inspection and maintenance program. The simulation results in multiple excesses of air quality standards for carbon monoxide and a 100-200 percent increase in the annual average levels of this pollutant.

The carbon monoxide analysis reveals the importance of the Vehicular Emission Standards. Yet, one must ask "what happens if they are not actively enforced through an inspection and maintenance program?" The Sonoma County Advanced Planning Division concerned themselves with this question by conducting an impact analysis of different levels of enforcement on downtown Santa Rosa.

Figure VI-29 provides the effects of 1975, 1980 and 1990 levels of enforcement of emission control device requirements for the years 1980, 1990 and 2000. It shows, for example, what the concentration of CO would be in 1990 if both the inspection and maintenance program and the improvement of emission control devices are stopped in 1975 or 1980 or 1990. In the case of this example, the elimination of the emission control device programs in 1975 would result in the violation of the Federal 8-hour standard. Yet, the concentrations would be well below the standard if the programs were stopped in 1980. This finding shows the importance of the emission device control programs as compared to other air pollution abatement programs such as limiting the number of cars in a particular area. However, what should also be noted in Figure VI-29 is that beyond 1990, when the emission device control programs are estimated to reach their peak effectiveness, pollution concentration will again start to increase due to increased number of cars (due to population and employment increases) in the study area. At this time period, land use growth and public transportation strategies will become increasingly important as a means of reducing car travel, and hence population emission.

Impacts of Development on the Emission of Particulates. Suspended particulate is a good indicator of growth impact. While carbon monoxide strongly reflects the impact of autos, particulate matter is



CARBON MONOXIDE
SRC 478-PROJECTION YEAR 2000
WITH 1973 VEHICLE EMISSION REQUIREMENTS
Healdsburg
Rt. 128
Rt. 116
Guerneville Rd.
Sebastopol
Rt. 12
Santa Rosa
Rt. 1
Rt. 116
Cotati
Rohnert Park
Petaluma
Sonoma
Rt. 116
Rt. 12
Annual Average Concentrations
3.0 ppm (3435 μg/m³)
8-hour Federal Standard exceeded more than 20 days per year
2.0-3.0 ppm (2290 - 3435 μg/m³)
8-hour Federal Standard exceeded 3-20 days per year
1.5-2.0 ppm (1718 - 2290 μg/m³)
8-hour Federal Standard exceeded 1-3 days per year
1.0-1.5 ppm (1145 - 1718 μg/m³)
No Standard Exceedances
0.75-1.0 ppm (859 - 1145 μg/m³)
No Standard Exceedances
0 4 8 KM
0 5 MILES
N

FIG. VI–27

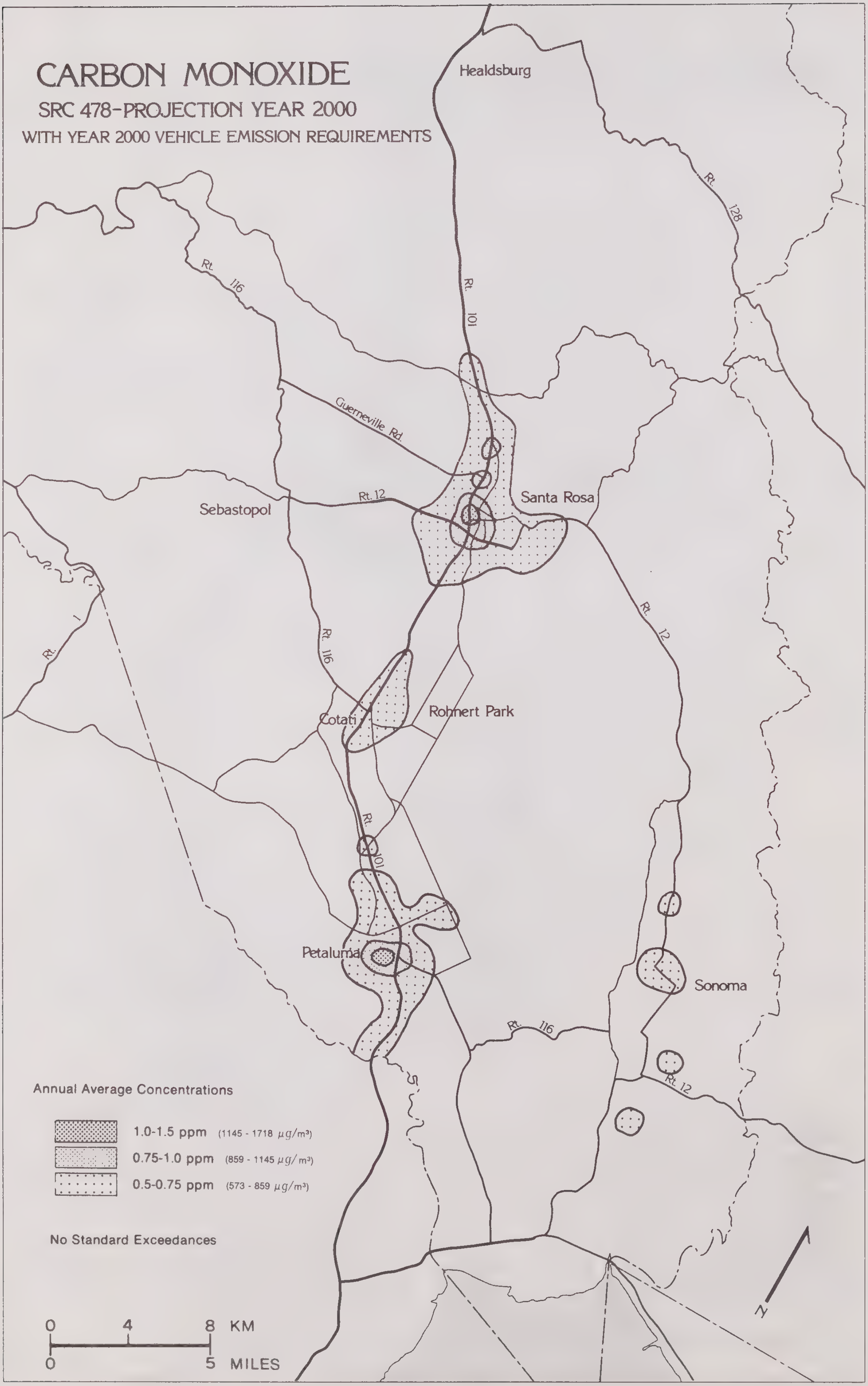

CARBON MONOXIDE
SRC 478-PROJECTION YEAR 2000
WITH YEAR 2000 VEHICLE EMISSION REQUIREMENTS
Healdsburg
Rt. 128
Rt. 116
Rt. 101
Guerneville Rd.
Rt. 12
Santa Rosa
Sebastopol
Rt. 1
Rt. 116
Rt. 12
Cotati
Rohnert Park
Rt. 101
Petaluma
Sonoma
Rt. 116
Rt. 12
Annual Average Concentrations
1.0-1.5 ppm (1145 - 1718 μg/m³)
0.75-1.0 ppm (859 - 1145 μg/m³)
0.5-0.75 ppm (573 - 859 μg/m³)
No Standard Exceedances
0 4 8 KM
0 5 MILES
N

FIG. VI–28

EFFECT OF VEHICLE EMISSION INSPECTION/MAINTENANCE PROGRAM:

DOWNTOWN SANTA ROSA

CARBON MONOXIDE AT 478,000 POPULATION LEVEL

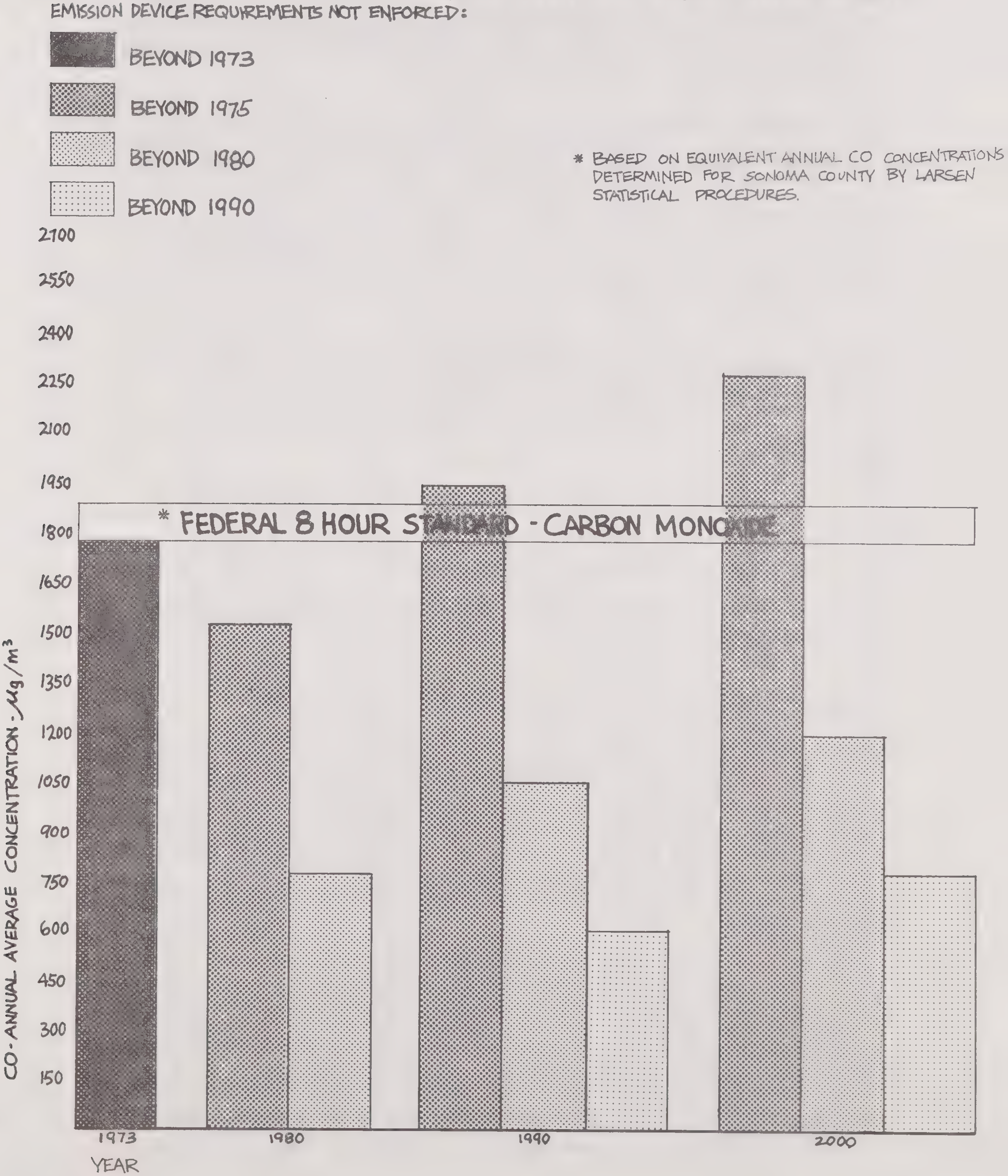


FIG. VI-29

more closely related to non-vehicular pollutant sources such as industrial and commercial activity and the dust and dirt associated with everyday human activity. Beyond existing stationary source controls, little is envisioned at present of a technological nature in controlling particulates. Therefore, increased growth will tend to be associated with increased particulate pollution.

Particulates in Sonoma County may pose a major problem in the year 2000 due to the increased population using heating fuels. Frequent excesses of standards are anticipated for each land use alternative. Table VI-12 shows the projected annual average maximum concentrations at four selected urban areas and the frequency with which the 24-hour State standard of 100 micrograms per cubic meter can be expected to be exceeded. It should be noted that the peak annual averages do not always occur in the same grid cells due to the varying pattern of emissions between scenarios.

From the regional growth perspective, Rural Dispersed 478 and Continuing Trends 478 have the lowest concentrations of particulates and Santa Rosa Centered 630 and Urban Centered have the highest.

Figures VI-30 to VI-33 illustrate the isopleths of particulates. The maps show:

1) the highest concentrations in locations of high density residential

2) the widest dispersion when residential development spreads

This, therefore, highlights that particulate concentrations will follow population concentrations as distinct from vehicle trips.

Impact of Development on the Emission of Sulfur Dioxide

There is presently little sulfur dioxide being emitted from man-made sources in Sonoma County. However, a potential conversion to sulfur-containing fuels, an increased population, and enhanced industrial activity will substantially raise future SO_2 levels over present conditions. However, State 24-hour SO_2 standard in the year 2000 is not expected to be exceeded except for isolated situations near Petaluma where large point sources -- parimarily industrial boilers -- will cause localized elevated levels that may occasionally exceed standards.

Figure VI-34 illustrates the output from the diffusion model for SRC 478 which shows that standards will be exceeded up to 35 days per year for portions of Petaluma and Santa Rosa. However, by comparing the output of the model with the very limited monitoring data available, and in evaluating sulfur dioxide elsewhere in the Bay Area, it is felt that these figures may be as much as 50 percent too high. This would drop the maximum anticipated annual average concentration down to 0.01 ppm and therefore cause the 24-hour standard to be exceeded only 1 to 4 days per year.

TABLE VI-12

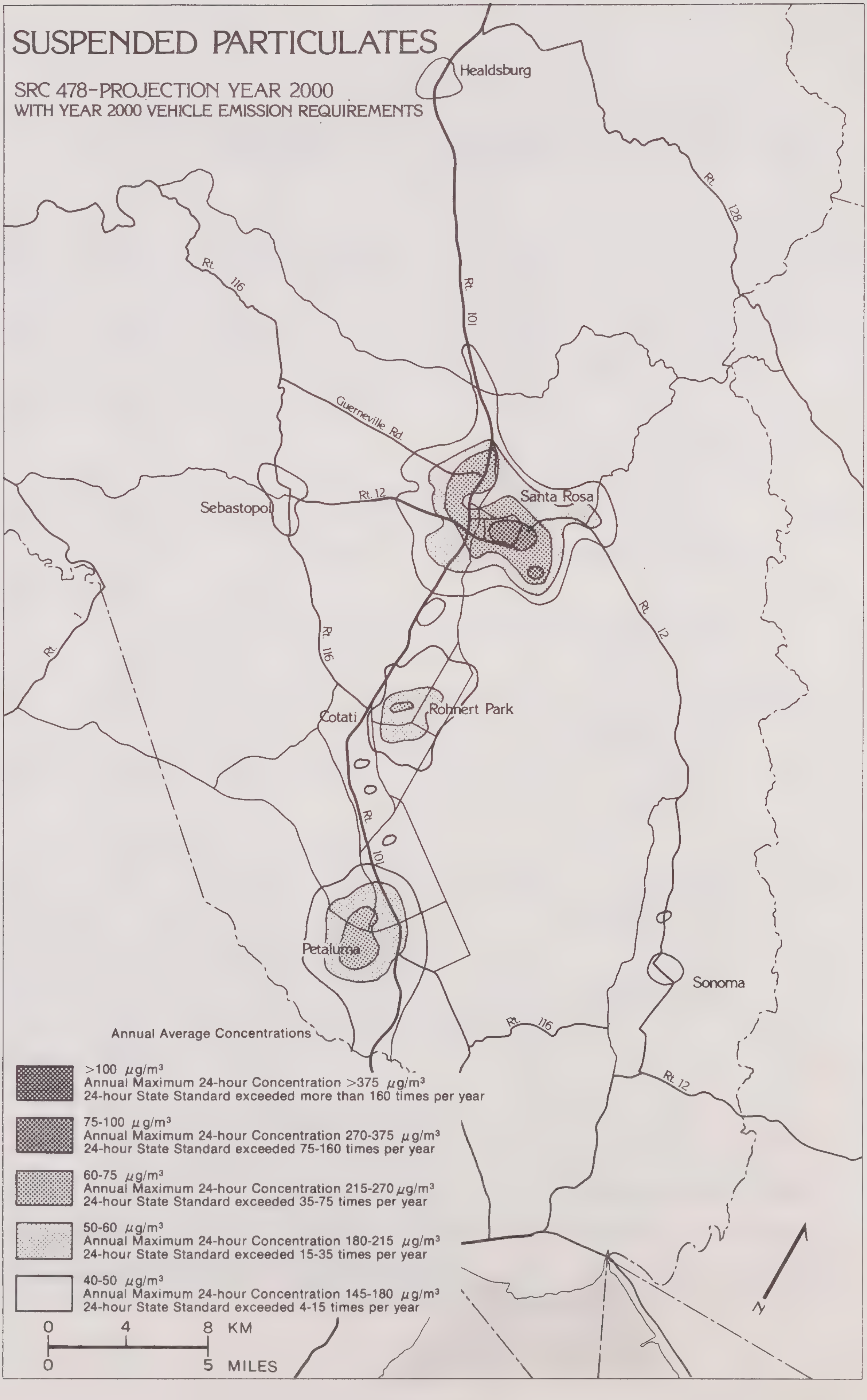
ANNUAL AVERAGE CONCENTRATION ($\mu g/m^3$) AND FREQUENCY OF EXCEEDANCE OF STATE 24-HOUR STANDARD FOR PARTICULATES

LAND-USE ALTERNATIVE		SANTA ROSA	ROHNERT PARK-COTATI	SONOMA	PETALUMA[3]
SRC 478	An. Avg.[1]	89	65	49	65
	No. Days[2] Std. exceeded	(116)	(46)	(14)	(46)
SRC 630	An. Avg.	126	72	56	75
	No. Days Std. exceeded	(167)	(65)	(26)	(70)
UC 478	An. Avg.	85	68	77	75
	No. Days Std. exceeded	(97)	(53)	(80)	(70)
UC 630	An. Avg.	91	74	80	80
	No. Days Std. exceeded	(124)	(66)	(90)	(90)
SD 478	An. Avg.	68	59	52	60
	No. Days Std. exceeded	(53)	(32)	(23)	(35)
SD 630	An. Avg.	71	60	59	70
	No. Days Std. exceeded	(61)	(35)	(32)	(58)
RD 478	An. Avg.	65	58	40	60
	No. Days Std. exceeded	(46)	(29)	(5)	(35)
BY	An. Avg.	48	41	31	50
	No. Days Std. exceeded	(12)	(7)	(0)	(16)
CT 478	An. Avg.	65	58	42	60
	No. Days	(46)	(16)	(9)	(35)

[1] Annual average ($\mu g/m^3$).

[2] Number of days 24-hour State Standard (100 $\mu g/m^3$) will be exceeded.

[3] Calibrated concentration based on Petaluma monitoring and monitoring of similar cities in the San Francisco Bay Area.



SUSPENDED PARTICULATES
SRC 478-PROJECTION YEAR 2000
WITH YEAR 2000 VEHICLE EMISSION REQUIREMENTS
Healdsburg
Rt. 128
Rt. 116
Rt. 101
Guerneville Rd.
Rt. 12
Sebastopol
Santa Rosa
Rt. 1
Rt. 116
Rt. 12
Cotati
Rohnert Park
Rt. 101
Petaluma
Sonoma
Rt. 116
Rt. 12
Annual Average Concentrations
>100 µg/m³
Annual Maximum 24-hour Concentration >375 µg/m³
24-hour State Standard exceeded more than 160 times per year
75-100 µg/m³
Annual Maximum 24-hour Concentration 270-375 µg/m³
24-hour State Standard exceeded 75-160 times per year
60-75 µg/m³
Annual Maximum 24-hour Concentration 215-270 µg/m³
24-hour State Standard exceeded 35-75 times per year
50-60 µg/m³
Annual Maximum 24-hour Concentration 180-215 µg/m³
24-hour State Standard exceeded 15-35 times per year
40-50 µg/m³
Annual Maximum 24-hour Concentration 145-180 µg/m³
24-hour State Standard exceeded 4-15 times per year
0 4 8 KM
0 5 MILES
N

FIG. VI-30

SUSPENDED PARTICULATES

SRC630-PROJECTION YEAR 2000

WITH YEAR 2000 VEHICLE EMISSION REQUIREMENTS

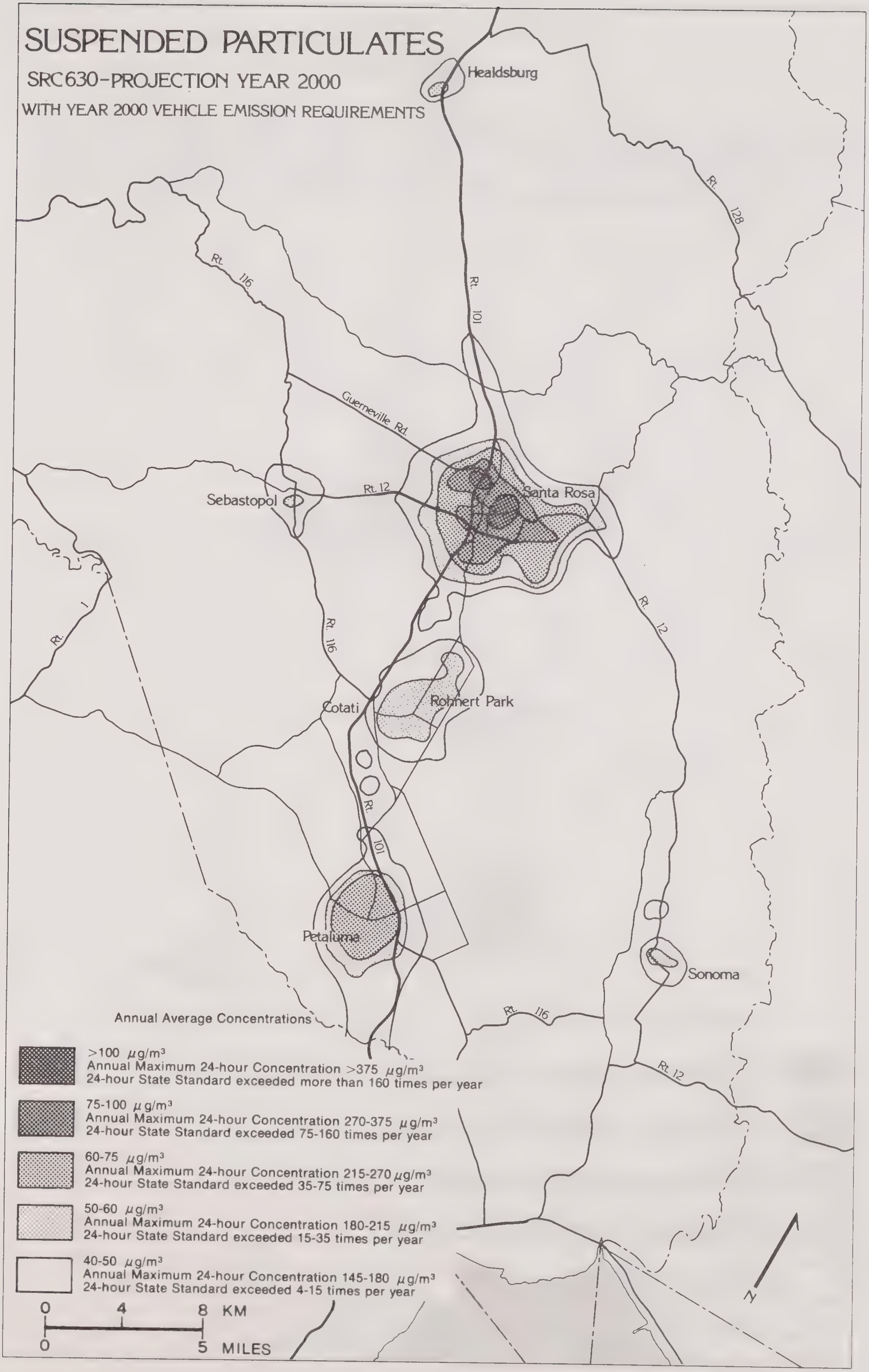
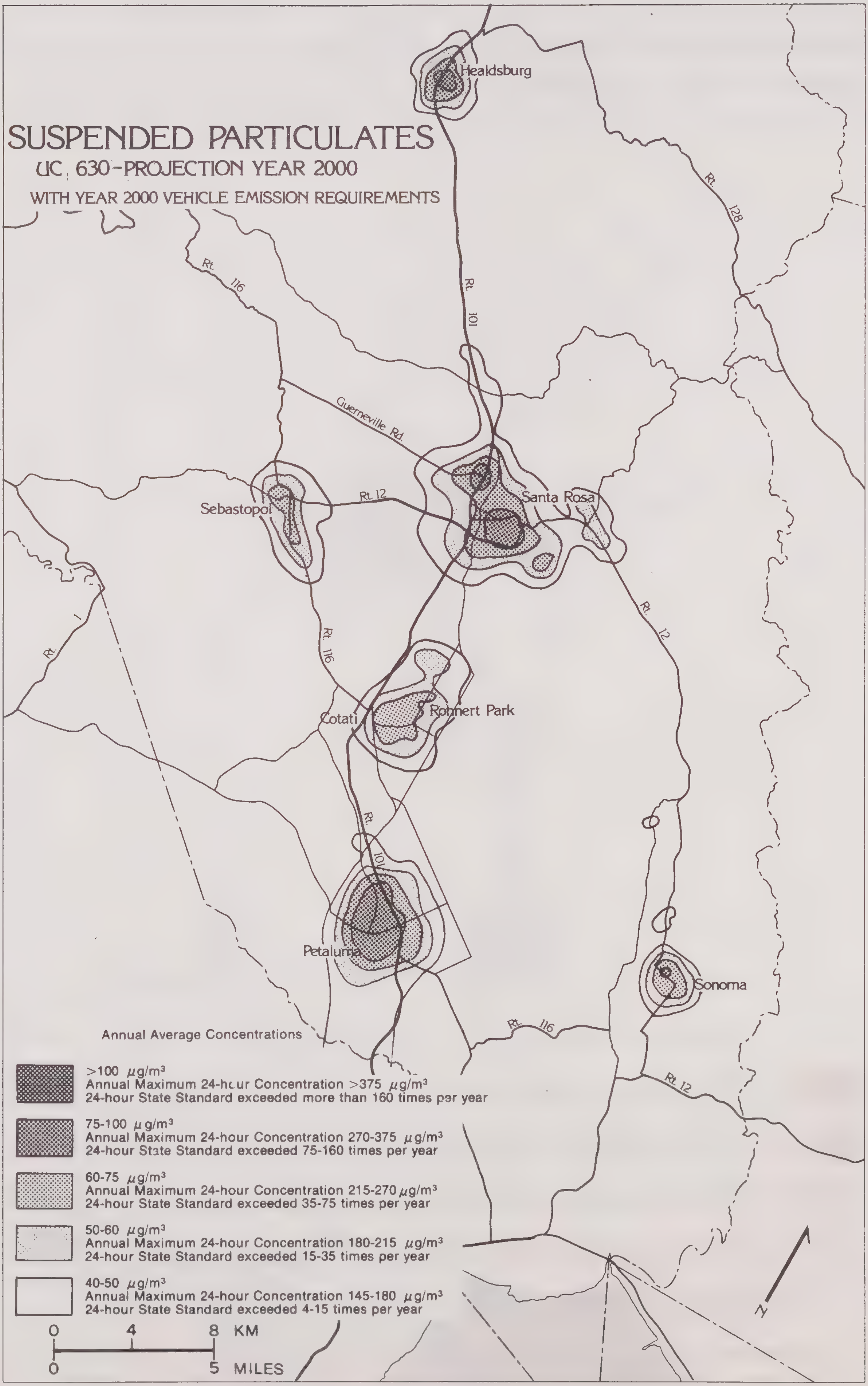


FIG. VI-31



SUSPENDED PARTICULATES
UC 630-PROJECTION YEAR 2000
WITH YEAR 2000 VEHICLE EMISSION REQUIREMENTS
Healdsburg
Rt. 128
Rt. 116
Rt. 101
Guerneville Rd.
Rt. 12
Sebastopol
Santa Rosa
Rt. 1
Rt. 116
Rt. 12
Cotati
Rohnert Park
Rt. 101
Petaluma
Sonoma
Rt. 116
Rt. 12
Annual Average Concentrations
>100 μg/m³
Annual Maximum 24-hour Concentration >375 μg/m³
24-hour State Standard exceeded more than 160 times per year
75-100 μg/m³
Annual Maximum 24-hour Concentration 270-375 μg/m³
24-hour State Standard exceeded 75-160 times per year
60-75 μg/m³
Annual Maximum 24-hour Concentration 215-270 μg/m³
24-hour State Standard exceeded 35-75 times per year
50-60 μg/m³
Annual Maximum 24-hour Concentration 180-215 μg/m³
24-hour State Standard exceeded 15-35 times per year
40-50 μg/m³
Annual Maximum 24-hour Concentration 145-180 μg/m³
24-hour State Standard exceeded 4-15 times per year
0 4 8 KM
0 5 MILES
N

FIG. VI–32

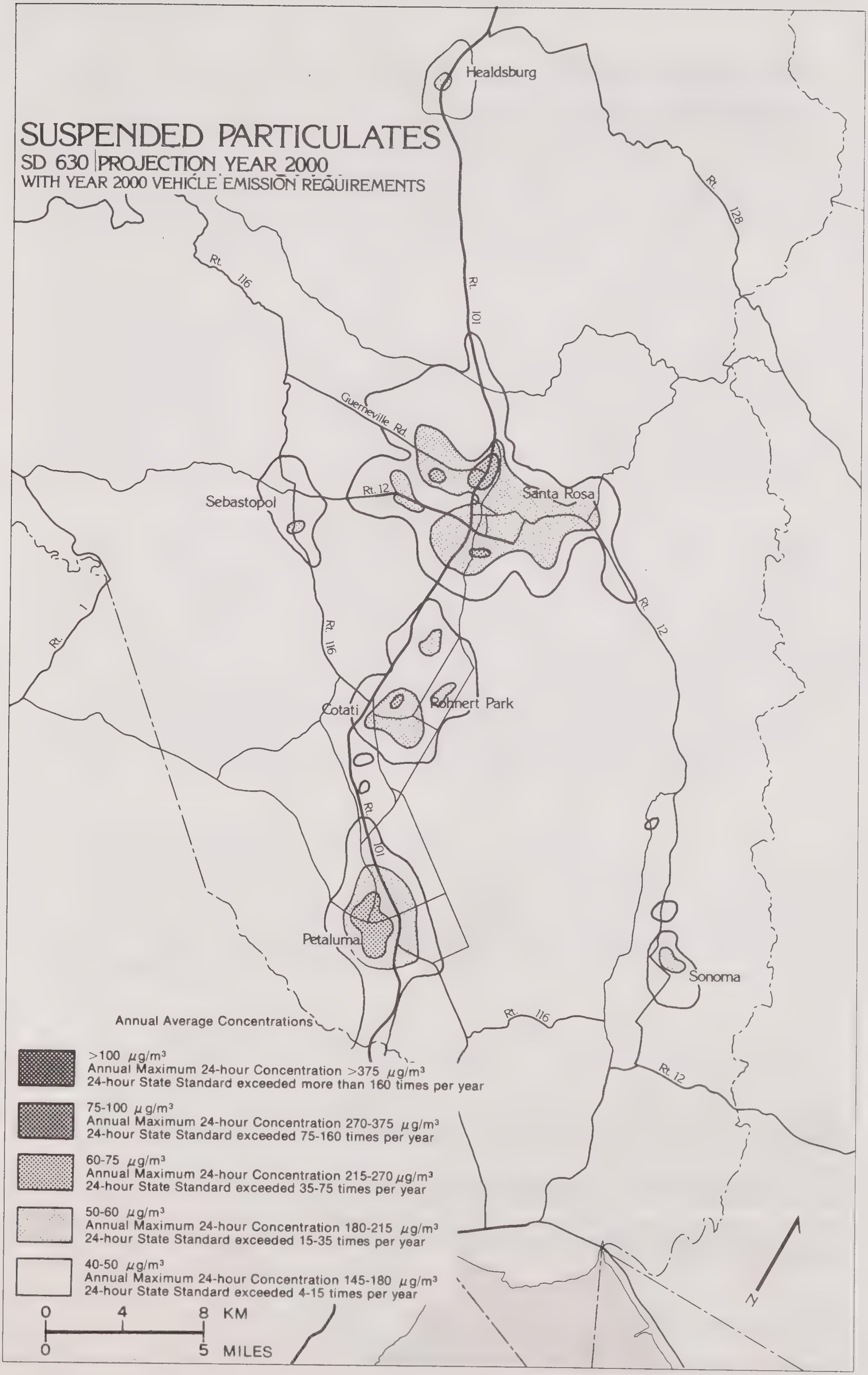
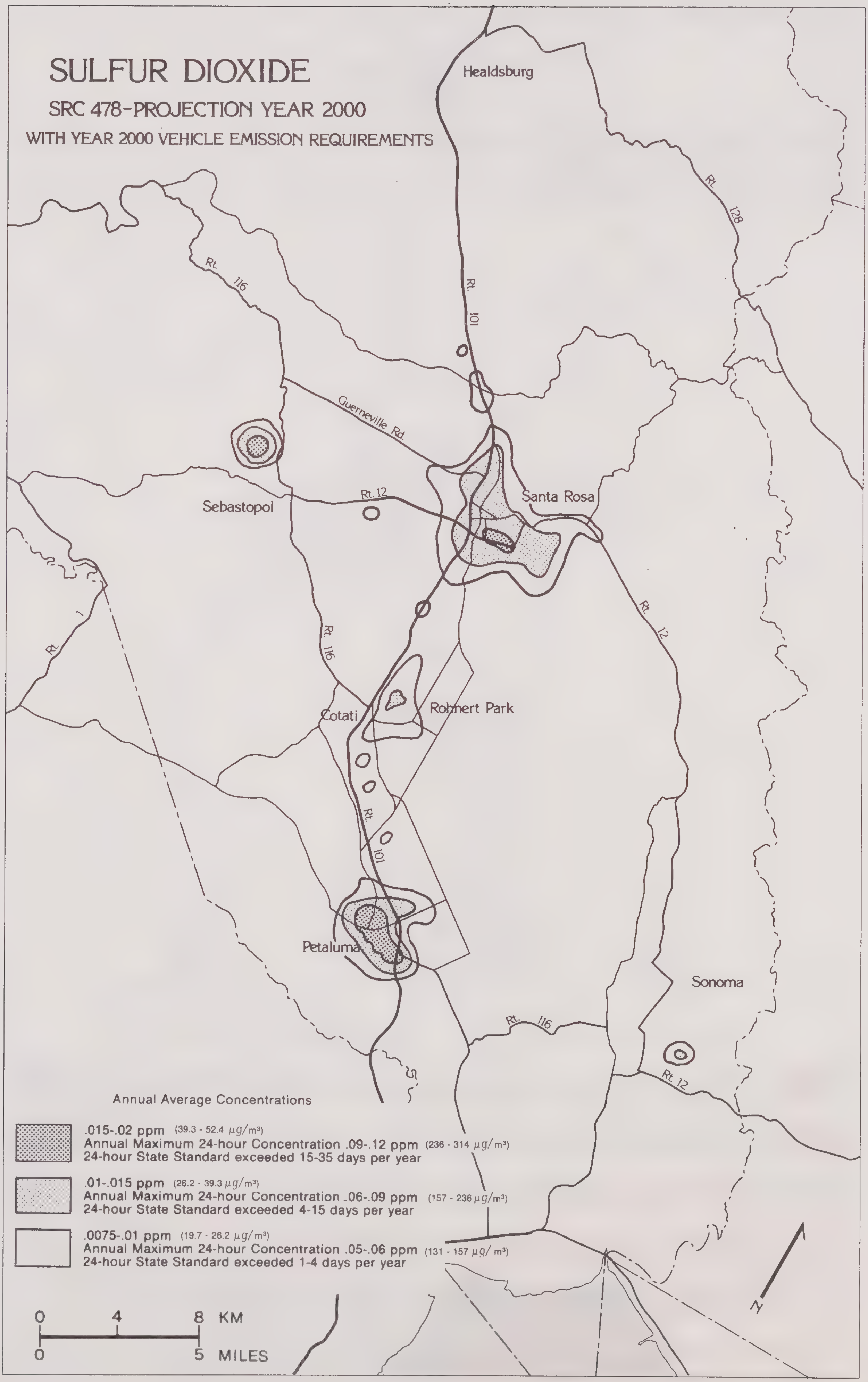

SUSPENDED PARTICULATES
SD 630 PROJECTION YEAR 2000
WITH YEAR 2000 VEHICLE EMISSION REQUIREMENTS
Healdsburg
Rt. 128
Rt. 116
Rt. 101
Guerneville Rd.
Rt. 12
Sebastopol
Santa Rosa
Rt. 1
Rt. 116
Rt. 12
Cotati
Rohnert Park
Rt. 101
Petaluma
Sonoma
Rt. 116
Rt. 12
Annual Average Concentrations
>100 µg/m³
Annual Maximum 24-hour Concentration >375 µg/m³
24-hour State Standard exceeded more than 160 times per year
75-100 µg/m³
Annual Maximum 24-hour Concentration 270-375 µg/m³
24-hour State Standard exceeded 75-160 times per year
60-75 µg/m³
Annual Maximum 24-hour Concentration 215-270 µg/m³
24-hour State Standard exceeded 35-75 times per year
50-60 µg/m³
Annual Maximum 24-hour Concentration 180-215 µg/m³
24-hour State Standard exceeded 15-35 times per year
40-50 µg/m³
Annual Maximum 24-hour Concentration 145-180 µg/m³
24-hour State Standard exceeded 4-15 times per year
0 4 8 KM
0 5 MILES
N

FIG. VI-33



SULFUR DIOXIDE
SRC 478-PROJECTION YEAR 2000
WITH YEAR 2000 VEHICLE EMISSION REQUIREMENTS
Healdsburg
Rt. 128
Rt. 116
Rt. 101
Guerneville Rd.
Sebastopol
Rt. 12
Santa Rosa
Rt. 12
Rt. 1
Rt. 116
Cotati
Rohnert Park
Rt. 101
Petaluma
Sonoma
Rt. 116
Rt. 12
Annual Average Concentrations
.015-.02 ppm (39.3 - 52.4 μg/m³)
Annual Maximum 24-hour Concentration .09-.12 ppm (236 - 314 μg/m³)
24-hour State Standard exceeded 15-35 days per year
.01-.015 ppm (26.2 - 39.3 μg/m³)
Annual Maximum 24-hour Concentration .06-.09 ppm (157 - 236 μg/m³)
24-hour State Standard exceeded 4-15 days per year
.0075-.01 ppm (19.7 - 26.2 μg/m³)
Annual Maximum 24-hour Concentration .05-.06 ppm (131 - 157 μg/m³)
24-hour State Standard exceeded 1-4 days per year
0 4 8 KM
0 5 MILES
N

FIG. VI–34

Ambient SO_2 concentrations are predominantly caused by major point sources, and not so much by changing land use plans. Therefore, because the locations of the major point sources are predominately near Petaluma and they overwhelm other pollution sources, little if any difference can be seen among land use alternatives. Consequently, only the analysis on Santa Rosa 478 was made. Near the Santa Rosa and Rohnert Park urban areas, the pattern of concentration would change among alternatives similar to that for particulates because each pollutant is generated primarily by population.

Reactive Pollutants - Oxidant

The oxidant analysis applied a modified proportional rollback technique to determine the effect of future growth pattern changes on oxidant concentrations. Although the shortcomings of proportional rollback techniques are well-known, it was the only method judged feasible for this study. The modification of using inter-basin transport calculations with the usual rollback analysis has made its application to this study reasonable and useful.

A basic problem in applying the rollback approach to a specific area, such as Sonoma County, is that oxidant concentrations are not only a function of emissions in Sonoma County but of emissions in other sections of the Bay Area. Furthermore, different areas in Sonoma County are affected differently by transported emissions. On one extreme, oxidant concentrations in various areas of Sonoma County can be assumed to be proportional to County emissions only. On the other extreme, oxidant concentrations in various areas of Sonoma County can be assumed to be proportional to emissions of the entire San Francisco Bay Area Basin. A weighting approached, developed by the BAAPCD, was used to estimate the transport of emissions from each County to Sonoma.

Impact of Development on the Creation of Oxidant

Nine separate future land use patterns were evaluated for their effect on oxidant concentrations in the year 2000. Non-methane hydrocarbon emissions for each of the scenarios were derived from grid cell information. Emissions for each of the other counties and for the base year (1973) were calculated by the Bay Area Air Pollution Control District.

Table VI-13 presents the results of the oxidant analysis. This is presented in terms of the Santa Rosa basin, Petaluma basin and Valley of the Moon (Sonoma). The severity of oxidant pollution is represented by annual maximum hourly concentration and number of times the 1-hour National Ambient Air Quality Standard is exceeded.

The present oxidant situation in Sonoma County is presented in the first row. Although Santa Rosa has the largest population (and emissions), it has the least severe oxidant problem at present. Conversely, Sonoma has the smallest population and experiences the most severe oxidant problem. The primary reason for this difference

TABLE VI-13

ANNUAL MAXIMUM HOURLY CONCENTRATIONS ($\mu g/m^3$) AND FREQUENCY OF EXCEEDANCE OF FEDERAL 1-HOUR STANDARD FOR OXIDANT

Land-Use Alternative		Oxidant Pollution At Santa Rosa	At Petaluma	At Sonoma	Total Hours Over Standard
BY[1]	Annual Max.	235	274	333	
	No. of times Std. exceeded	9 hours	22 hours	96 hours	127
SRC 478	Annual Max.	274	274	333	
	No. of times Std. exceeded	29 hours	29 hours	88 hours	146
SRC 630	Annual Max.	353	333	372	
	No. of times Std. exceeded	100 hours	66 hours	149 hours	315
SD 478	Annual Max.	235	294	372	
	No. of times Std. exceeded	9 hours	48 hours	166 hours	223
SD 630	Annual Max.	333	353	412	
	No. of times Std. exceeded	88 hours	134 hours	219 hours	441
UC 478	Annual Max.	235	333	392	
	No. of times Std. exceeded	8 hours	88 hours	202 hours	298
UC 630	Annual Max.	294	412	451	
	No. of times Std. exceeded	48 hours	306 hours	438 hours	792
RD 478	Annual Max.	196	255	353	
	No. of times Std. exceeded	2 hours	14 hours	105 hours	121
Cont. Trends 478	Annual Max.	255	294	333	
	No. of times Std. exceeded	11 hours	33 hours	88 hours	134
Cont. Trends 630	Annual Max.	294	353	392	
	No. of times Std. exceeded	35 hours	96 hours	202 hours	333

[1] Calculated annual maximum and number of times standard exceeded -- very close to actual monitored values.

is the amount of transport to each area. The analysis estimates that present oxidant concentrations in the Santa Rosa area caused mostly by local sources, with an estimated three percent caused by transport on the average. Forty percent of Petaluma's oxidant concentrations are caused by transport while sixty-three percent of Sonoma's oxidant is caused by transport. These figures are for the present situation and represent estimates based on analysis of the wind-flow patterns. These results should be viewed with caution since the nature of the oxidant transport phemonena is not well understood and subject to considerable uncertainty and variation.

The last column in Table VI-13 presents estimates of the total hours over the oxidant standard for all three locations and all nine alternatives. These estimates are seen as the most valid comparison of alternatives based on the analysis conducted for this study. In all cases the 478,000 population level alternatives produce substantially less oxidant than the 630,000 population level alternatives. In fact, the 478,000 alternatives typically resulted in less than half the number of hours over the oxidant standard compared to the 630,000 alternatives.

Rural Dispersed 478,000 is the only alternative that is estimated to cause fewer days over the oxidant standard than at present. It, therefore, is the most favorable alternative from an oxidant pollution standpoint. (It should be noted that detailed traffic modeling was not done on the Rural Dispersed Alternative.) A look at the rest of the alternatives shows that the Santa Rosa Centered and Continuing Trends are the next most favorable at both population levels, while Urban Centered causes the most oxidant pollution at both population levels. Suburban Dispersed falls in between the least and most desirable alternatives.

Examination of Table VI-13 shows that although the above conclusions are applicable county-wide, specific areas do not always follow the general trends. For example, the Santa Rosa Centered alternatives cause the most oxidant pollution in Santa Rosa while being favorable county-wide, and the Urban Centered is one of the most favorable in Santa Rosa while being the least favorable county-wide. This observation is a direct result of the substantial amount of transported oxidants to Petaluma and Sonoma and the lack of appreciable transport to Santa Rosa.

The analysis conducted suggests that development in Petaluma or Sonoma is less desirable than development in Santa Rosa. Although increased hydrocarbon sources in Santa Rosa will increase oxidant pollution in that basin proportionately more than the other air basins, the magnitude of the effect on oxidants will be smaller than in Petaluma or Sonoma. For example, the estimated increase between Base Year and Suburban Dispersed 630, as measured in hours over the standard, is 79 hours in the City of Santa Rosa. This increase is associated with a 38 percent increase in hydrocarbon emission. The same land use alternative shows an increase of 112 hours and 123 hours over the standard in Petaluma and Sonoma, respectively, with the associated hydrocarbon

increases of 28 percent and 4 percent. Due to the fact that Santa Rosa receives less transported oxidants, a proportionately greater increase in hydrocarbon emissions in Santa Rosa creates a lesser increase in the number of hours over the standard than in either Petaluma or Sonoma.

A final point to be noted in Table VI-13 is that the maximum concentrations shown are directly proportional to the total hydrocarbon burden causing the local and transported oxidant concentrations. The number of hours over the standard, however, are not directly proportional but increase at a faster rate than emissions. This observation is due to the log-normal type frequency distribution and is an important observation to note when assessing the different future land use alternatives.

CHAPTER VII - LINKAGES BETWEEN LAND USE, AIR QUALITY AND WATER QUALITY

The air modeling confirms the findings from earlier studies that regional and urban form influence the distribution of air pollutants. Conversely, the water modeling results, particularly those associated with surface water runoff, demonstrate that spatial pattern of land use has only a modest impact on water quality in the entire basin although it may have significant impacts on particular stream segments. Therefore, since there were clear correlations between spatial form and the distribution of air pollutant concentrations but only minimal correlations between spatial pattern and water quality, it is no surprise that there was only a minimal correlation among spatial patterns to promote air quality and those to promote water quality.

The study also establishes that the land use/air quality/water quality linkages can vary with the pollutant being measured and the location where the measurement is made. This chapter describes the linkages that were investigated in the study and defines some of the policy considerations that are implied from the findings.

GENERAL CONCLUSIONS

The basic conclusions reached in this study are: 1) the assimilative capacity of air and water basins are key determinants of future levels of population and employment activities that can take be supported within basins without violating environmental standards; 2) the population and employment size and density are the most critical factors affecting both air and water quality as compared to other variables such as location, land use type or meteorological conditions (excluding reactive air pollutants); and 3) other pollution control approaches such as site specific land management techniques generally have greater influence on air and water quality than variations in spatial configurations or intensity of land use.

The combination of the natural features in an air or water basin, whether hydrological or meteorological, are critical factors in determining the concentration and distribution of pollutants in the basin. The concept of assimilative capacity, defined in this study as the ability of the physical environment to absorb pollutants without violating air and water quality standards, is an excellent mechanism by which planners can measure the influence of differing levels of land use or transportation activities on environmental quality objectives.

The assimilative capacity of a basin may be significantly different for air quality than for water quality. The Petaluma sub-basin, for example, has a relatively high assimilative capacity for water pollutants given the population and employment levels of the different land use alternatives. However, it has a relatively low assimilative capacity for oxidant.

The analysis of spatial pattern characteristics, including population and employment size, density, location and land use type, indicated that only the first two of these variables are particularly significant influences on levels of air and water quality. Other things being equal, the land use alternatives which concentrated population and employment produced the highest localized concentrations of non-reactive air pollutants and water pollutants. For example, the worst case situation for both air and water is the central section of Santa Rosa in the Santa Rosa Centered alternative, which is the largest and most densely populated pattern simulated. In this case the particulate concentrations, carbon monoxide concentrations and the total washoff loads entering nearby streams were the highest amounts of any simulation. Yet, when water pollution is measured on a regional level, in the receiving waters of an entire basin, there is very little difference between the quality levels produced by the various land use alternatives. When air pollution is measured in terms of population exposure to violations of these air quality standards, the centralized, compact spatial patterns result in far worse conditions.

There are several reasons why the interrelationships between air and water quality are not pronounced. The basic reason is that the hydrologic system and meteorological patterns in Sonoma County are essentially unrelated. The water quality in a stream draining one city in the County bears little relationship to the quality in a stream draining another city. Most obviously, the pollution washoff from Rohnert Park does not affect Santa Rosa because the two cities are not connected by a river. What may not be apparent, however, is that pollution from upstream cities is not always the important cause of pollution in downstream cities. As was seen in the surface runoff water quality analysis, pollution concentrations may be lower in downstream cities that those upstream due to the combined consequence of all the various characteristics that make up a hydrologic area including differing rainfall patterns, topography, soils or intervening land use. The pollution washoff from a 100 hectare (247 acres) orchard one kilometer (.621 miles) upstream from a city may have far greater impact than a 1,500 hectare city three kilometers further upstream.

On the other hand, some air pollutants are subject to a high degree of transport among cities. Air pollutants are transported not only across water basin boundaries within Sonoma County, but they are also transported to and from other parts of the San Francisco Bay Region. It is this dissimilarity in the characteristics of water basins versus air basins and the methods by which the pollutants are transported that results in the lack of linkages between land use patterns that support air quality as opposed to those which support water quality.

The combined effect of both of these findings -- the importance of assimilative capacity and population/employment levels -- provides the key to developing an environmental management strategy. For land use planning purposes population and employment levels provide a mechanism for relating assimilative capacity to urban growth. Assimilative capacity can be defined in terms of a combined population and

employment level, based on a clearly defined set of assumptions on the population generating potential of each of these variables. These assumptions would include wastewater generation, sewage treatment levels, compliance with auto emission standards and vehicle trip volumes. In this manner, population and employment provides a convenient measure to use in evaluating differing land use, transportation and infrastructure strategies aimed at achieving development patterns that aid in the achievement of air and water quality objectives. If the assumed requirements or influences of population and employment produce pollution levels in a basin that exceed either its air or water assimilative capacity, then different growth management efforts or mitigation measures would need to be considered.

The next sections of the chapter will describe in some detail the various linkages which were observed. They are classified in terms of spatial patterns, assimilative capacity and mitigation measures.

SPATIAL PATTERN LINKAGES

The influence of spatial patterns on air and water quality linkages are determined by comparing the air and water modeling results from the different land use alternatives. For this purpose it is first helpful to re-classify the land use alternatives in terms of their basic properties.

1) Population growth distribution

   Regional urban - rural population distribution (highly urban population vs. highly rural population)

   Regional distribution of urban population (high population in a single city vs. population divided more evenly among several cities)

   Regional distribution of urban employment (high employment in a single city vs. employment divided more evenly among several cities)

2) Land use intensity distribution

   Residential density (high vs. low percentage of high density dwelling units)

   Commercial densities (high vs. low number of employees per acre in city center)

3) Land use spatial distribution (local)

   Residential location (high vs. low percentage of dwelling units located close to city centers)

   Commercial locations (high vs. low percentage of businesses located close to city centers)

Figure VII-1 is designed to illustrate the relative position of each of the alternatives in relation to the growth characteristic listed above. The extremes for each characteristic are at either end of a line. These are extremes in relation to each other and not to some absolute standards. For example, in the case of the regional distribution of urban population (second diagram in figure VII-1) the Santa Rosa Centered alternatives are found to concentrate 60% of the County's urban population in Santa Rosa, while the Urban Centered alternatives locate only 30% of the County's urban population there. Santa Rosa, in the other three alternatives, contains about 50% of the County's urban population, so these alternatives are shown just to the left of the midpoint of the line.

Regional Urban-Rural Population Distribution

The alternative with a high rural population and low urban population (Rural Dispersed) produces the lowest levels for most air and water pollutants. There are several reasons for this result:

1) The population of all the cities are lowest of all the alternatives; thus traffic volumes, population-based air emissions (e.g., space heating emissions) and water pollutant loadings were the lowest in each city.

2) Population and employment densities are low in both cities and rural areas, resulting in lower concentrations of pollutant generators.

3) The rural residential land use has the lowest water pollutant loadings of all the residential land uses.

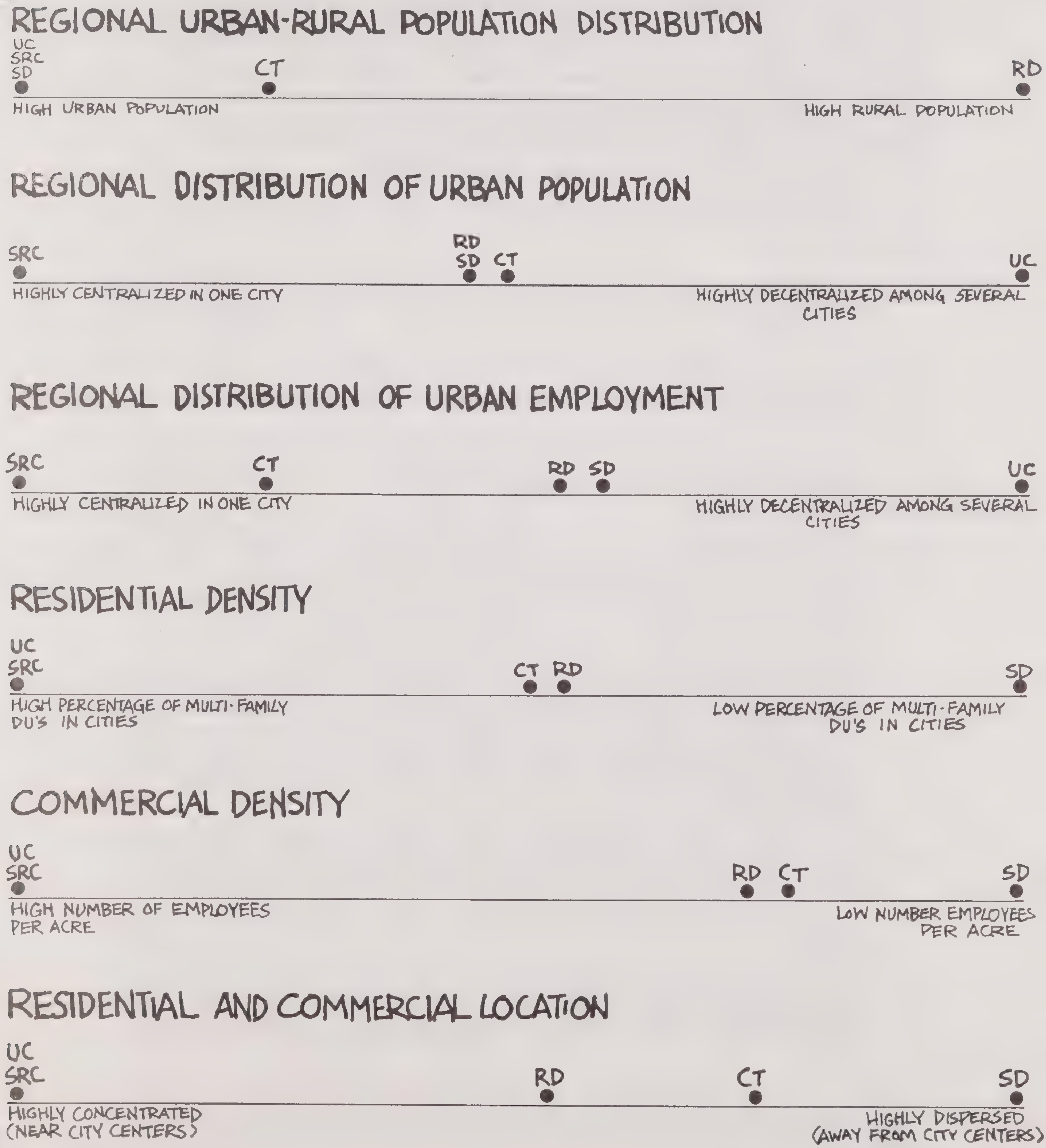
4) Rural residential land use, at one house per three acres, is the housing pattern that provides the smallest amount of impervious surface coverage thereby permitting more water to be absorbed in the open space rather than running off into the nearby streams.

In the case of oxidant, the Rural Dispersed alternative is actually better than in 1973 for two of the air basins (Santa Rosa and Petaluma). This improvement occurs because the reduction in the year 2000 hydrocarbon emission rates due to emission control devices more than offsets the population increase in this alternative.

Regional Distribution of Urban Population and Employment

The effects of centralizing or decentralizing population and employment are discussed together because both of these variables are treated the same in the land use alternative and their effects are not separated by the modeling analysis.

FIGURE VII-1
CHARACTERISTICS OF LAND USE ALTERNATIVES



Concentrating high population and employment in one city in the County (the Santa Rosa Centered alternatives) produces both high air and water pollution levels in that one city. Decentralizing urban population among several cities (the Urban Centered alternatives) produces high air and water pollution levels in each of those cities, but the peak air pollution levels in each of the cities are lower than the peak levels encountered in Santa Rosa in the one-city concentrated alternative. Table VII-1 presents the population exposure rates in the study area in four of the land use alternatives.

The following is a summary of the general findings concerning the above variables:

1) The one-city centralized alternatives, SRC 478 and 630, produce the highest County peak concentrations of air pollutants, excluding oxidant.

2) The one-city centralized alternative produce very high population exposure levels for all non-reactive air pollutants in that city.

3) The total air pollutant population exposure in the County is comparable for both the centralized one-city alternatives and the decentralized multi-city alternatives.

4) In terms of exposure to high oxidant concentrations, the one-city centralized alternatives in the study area are far better than the multi-city centralized alternatives. This result is due to the transport phenomenon that brings Bay Area pollutants to Petaluma and Sonoma in much greater concentrations than to Santa Rosa. Even though the number of reactive hydrocarbons that are transported to Sonoma and Petaluma represent a small fraction of those produced throughout the San Francisco Bay Region, they are still enough to cause oxidant levels that exceed the standard. If Petaluma or Sonoma had been chosen as the site of the one-city centralized alternatives, then these alternatives would have been found to have been far worse than the multi-city decentralized alternatives.

5) The streams that drain Santa Rosa have high wet weather pollutant concentrations in the Santa Rosa Centered alternatives, and the streams that drain the other major cities in the county have high wet weather pollutant concentrations in the Urban Centered alternatives.

6) When water quality is measured at the outlet of the Laguna basin, there is little difference between the one-city centralized regional pattern (SRC) and the decentralized, multi-city pattern (UC).

Density and Location Characteristics of Residential and Commercial Land Uses

Because density and locational characteristics of residential and commercial uses are distributed similarly in the alternatives, it is not possible to separate the effects of each. Both Santa Rosa Centered

Table VII-1

Population Exposure Levels[1] of Air Contaminants
Per Land Use Alternative

	Santa Rosa Centered 478	Santa Rosa Centered 630	Urban Centered 478	Suburban Dispersed 478
Carbon Monoxide				
Population Exposure Index[2]	1.15×10^6	1.90×10^6	1.17×10^6	$.95 \times 10^6$
Population Exposure to Standard Violation Index[1]	None	None	None	None
Particulate				
Population Exposure Index[2]	101×10^6	155×10^6	103×10^6	91.3×10^6
Population Exposure to Standard Violation Index[1]	5.6×10^6	22.5×10^6	6.1×10^6	$.34 \times 10^6$

1. The key assumption in the Population Exposure to Standard Violation Index (PESVI) is that the degree of health hazard cause by an air pollution level is linearly related to the total population exposed to concentrations in excess of the standard and that pollution levels below the standard are not harmful. The PESVI is based on the Regional Population Exposure Level concept developed by the Rand Corporation in The Regional Impacts of Near-Term Transportation Alternatives: A Case Study of Los Angeles (Mikolowsky, 1974). The units of the population exposure indices used are person-parts per million for CO and person - $\mu g/m^3$ for particulates.

   The PESVI is intended only to provide an estimate of the relative difference among the land use alternatives and should not be treated as a precise calculation. While the pollutant concentrations can be estimated with reasonable accuracy, there is a potential for greater relative error when the value of the standard is subtracted from the projected concentrations.

   The PESVI is determined by the summation per air basin of the products of grid cell population and the difference between the 8-hour maxima for CO and 24-hour maxima for particulate concentrations and the pollutant standard per grid cell. As follows:

and Urban Centered alternatives are concentrated (e.g., densities were high and locations favored the city centers). The Suburban Dispersed alternatives have both low densities and locations favoring the periphery of cities. There are no alternatives that test dispersed high density residential within a city.

The following summarizes the conclusions relating to density and location. The reader is reminded that the air quality analysis did not take into consideration the possible changes in trip frequency or means of transportation that could occur with different centralized versus decentralized land use activity.

1) Concentrated development produces high localized concentrations of both air and water pollution.

2) Dispersed low density development results in relatively low pollution levels being spread over a large area.

3) Concentrations of commercial and industrial land uses produce the highest amount of water pollutants from surface runoff.

4) The population exposed to carbon monoxide or particulates, when measured in absolute terms (persons-μg./m3), is 1.2 times as large under the centralized and concentrated alternatives (SRC and UC) as the dispersed alternative (SD).

5) The population exposure to particulate levels above the State 24-hour standard is under the concentrated and centralized patterns (SRC and UC) than the dispersed alternative (SD).

The influence of the location of different land uses requires a detailed explanation. As was indicated in the chapter that described the surface water runoff model, both the amount of pollutant loadings and the percentage of land surface covered varies according to land use. Table VII-2 shows the washoff of total suspended solids from each land use. The last column in the table shows the concentrations (total pollutant emissions per volume of water) of total suspended solids in the runoff from the different land uses relative to low density residential.

$$\sum_{i=1}^{n} \text{Pop}_{\text{cell } i} \left(\text{Pollutant Concentration - Pollutant Standard}\right)_{\text{cell } i}$$

2. The summation in the study area of the products of grid cell population and predicted 8-hour maxima for CO and 24-hour maxima for particulate concentrations per grid cell.

$$\sum_{i=1}^{n} \text{Pop}_{\text{cell } i} \left(\text{Concentration of Pollutant}\right)_{\text{cell } i}$$

Table VII-2

Washoff Characteristics of Land Uses

Land Use	% Impervious Coverage	Pollutant Loads[1]	Relative Pollutant Loads[2] (compared to low density residential)	Relative Pollutant Concentrations[3] (compared to low density residential)
Low Density Residential	30	6.0	1.0	1.0
Medium Density Residential	65	13.7	2.3	1.0
High Density Residential	80	24.6	4.0	1.5
City Commercial	95	63.8	10.5	3.3
Suburban Commercial	90	63.8	10.5	3.5
Industrial	98	36.8	6.0	1.9

1. Kilograms of total suspended solids (TSS) per hectare (20 days of accumulation).

2. Kilograms of TSS per hectare divided by kilograms of TAS per hectare of low density residential.

3. TSS concentrations in runoff divided by TSS concentrations in runoff from low density residential.

It can be seen from Table VII-2 that the total pollution load from commercial land is nearly eleven times greater than that from low desnity residential and almost twice as great as the industrial washoff load. The industrial pollution load is six times greater than that of low density residential but only 50% more than the pollutants from high density residential.

The effects of these high pollutant loads on the contaminant concentrations in streams is lessened by the dilution caused by the higher volume of runoff from the higher intensity land uses. The first column of the table again gives the percent impervious coverage which indicates the relative volume of water that would run off from each land use.

When the water quality impact of the different land uses is measured in terms of the concentrations of total suspended solids, commercial land is about three and one-half times as high as single family residential. Industrial land use generates about twice the concentrations of single family housing and only 26% more than higher density housing.

As can be seen in Table VII-2, commercial land in a watershed or sub-area of a watershed can be the most critical land use in terms of the water quality in the streams which drain it. Industrial land is next in importance. Therefore, a plan which concentrates commercial development in a particular sub-area can clearly expect a far higher quantity of total suspended solids in the nearby streams than if a mixture of land uses were planned.

ASSIMILATIVE CAPACITY LINKAGES

The results of the modeling show that certain pollutants or pollution conditions are much less dependent on urban spatial patterns than others. Both the dry weather and wet weather water quality conditions are highly variable depending on the assimilative capacity of the watershed or hydrologic sub-area being studied. The volume of water flow in a particular section of a stream and the amount of contaminants entering the stream at a specific site are the critical factors in water quality.

The oxidant analysis indicates a similar relationship to assimilative capacity issues rather than urban spatial form. Wind-flow patterns, other meteorological characteristics and topographical features are the dominant influence on the distribution of oxidant. The linkages of assimilative capacity to these pollutants or pollution conditions will be described in the next sections.

Assimilative Capacity Characteristics and Wet Weather Water Quality

In general, urban development in small watersheds produces greater local pollution impact than development in large watersheds. For example, the wet weather water quality in the segment of Santa Rosa Creek that runs through downtown Santa Rosa is much higher than that in the stream that drains the northwest section of Santa Rosa, even though the highest concentration of urban development is in the downtown area. The reason is that the Santa Rosa Creek is longer and has a larger watershed that includes a substantial amount of open land in its upper reaches which provides relatively clean water to dilute the heavy washoff load from the center of Santa Rosa. The creek that drains the northwest section of Santa Rosa is short and has a small watershed with a small amount of open land. It therefore has only a minimal amount of water to dilute its urban runoff.

Other things being equal, it can be concluded that to attain a higher level of water quality, it is better to locate the greatest amount of urban development in large watersheds. If some development must occur in small watersheds, it would be best to limit it to those activities with the least potential washoff, such as a low density residential.

Assimilative Capacity Characteristics and Dry Weather Water Quality

Water quality in rivers during dry weather is essentially dependent on the population in the basin, the level of sewage treatment and the dry weather flow in the receiving water. It is this last variable that is linked to the assimilative capacity of the watershed. Because the dry weather model routed the effluent from homes, businesses, industries and other point sources to the sewage treatment plants, as is presently the case in the Sonoma study area, there was little difference in dry weather water quality from the alternatives due to variations in land use types or patterns. The differences that do appear are due to the impacts of the higher populations served at the various sewage treatment plants and, consequently, the higher effluent volumes.

The dry weather analysis indicates that the treatment plant at Petaluma can adequately accommodate higher levels of population due to both its treatment capability and to the assimilative capacity of the Petaluma River basin. The characteristics that combine to create the relatively larger assimilative capacity are 1) the high year-round river flow due to tidal influx from the Bay and 2) the large dilution capability of San Francisco Bay once the pollutants from the river are discharged into it.

The Laguna Basin, on the other hand, has a lower assimilative capacity to receive treated effluent during the dry weather periods. This is due to the complete lack of natural water flow in the rivers on which the sewage treatment plants were situated.

The major conclusion that can be drawn from the linkage between assimilative capacity and dry weather water quality is that the problems created by point source discharge, including both quality and quantity, can only be determined after the volume of the dry weather stream flow is first determined. The extent to which the stream flow is increased or decreased is determined by the totality of hydrologic characteristics (e.g., rainfall, land use, slope, channel characteristics, upstream impoundment and release, etc.). Therefore it is necessary to assess how the hydrologic characteristics of a watershed can vary or be altered before developing strategies for population size or sewage treatment facilities.

Assimilative Capacity and Oxidants

Oxidant concentrations and urban spatial patterns in Sonoma County are largely unrelated due to the nature of oxidant formation. Oxidant forms in the presence of sunlight after its precursor emissions (non-methane hydrocarbons and oxides of nitrogen) have thoroughly mixed in the atmosphere. Additionally, oxidant levels in two of the three basins in the study area are influenced by transport from other parts of the San Francisco Bay Region. If the effects of transport are removed from consideration, as is the case using the "rollback" technique the resulting oxidant levels are related only to the total emissions created in each of the three air basins (Santa Rosa, Petaluma, and Sonoma).

The Santa Rosa basin has the lowest oxidant levels of all the alternatives, except SRC 630, even though its population was between three and five times greater than that of the Petaluma basin and six to ten times that of the Sonoma basin (Valley of the Moon). The results suggest that the Santa Rosa air basin has a greater assimilative capacity than either the Petaluma or Sonoma basins. The three reasons for this greater capacity are 1) the topography of the Santa Rosa basin blocks the winds blowing up from the south but permits wind to blow in from the west 2) the distance is greater from the Santa Rosa basin to the major sources in the Bay Area and 3) the winds that blow into the basin from the west and north come from nominal source areas.

In contrast, the Petaluma basin is closer to the major sources from the south and does not have any protective barriers. The Sonoma basin is even more accessible to the sources of oxidant and has the added disadvantage of being a very narrow valley vulnerable to frequent inversions.

Determining the assimilative capacity of an air basin for oxidant is therefore a necessary first step in determining appropriate levels of population or employment and the various pollution generating activities they create. The use of the rollback technique, while of limited sophistication, does help to highlight the influence of the different topographic and meteorologic conditions on the level of oxidant. It provides planners with a first step toward determining whether growth limits may be necessary in particular sections of a region or the necessity of using different management control techniques when additional growth is permitted.

Similarly, the assessment of the assimilative capacity of a water basin compared to that of the air basin helps to define the areawide growth parameters in a planning strategy. Planning in those areas with a large assimilative capacity for both air and water could then proceed to reflect other issues related to growth distribution or environmental quality. The areas with limited assimilative capacity would need to focus on how to compensate for that restriction.

MITIGATION MEASURE LINKAGES

The modeling analysis which tested the effectiveness of site design/management control measures provides some of the most significant findings of the study. For water quality, the control measures include street sweeping, retention storage, and change in the amount of land covered by impervious surfaces. The air quality control measures tested are different levels of implementation of the car emission control devices. Both the air and water analyses indicate that site design/management control measures provide far more effective means of environmental improvement in the Sonoma study area than their spatial form counterparts. Because the site design/management control devices can be implemented to minimize or reduce the amount of pollutants created as a result of urbanization, they are termed mitigation measures.

Impact of Mitigation Measures on Water Quality

The mitigation devices tested by the model provide a strong indication of which devices are more effective than others in improving water quality. Retention storage appears to be the most effective control device, resulting in up to a twelve-fold reduction in peak concentration and total washoff over the original simulation. Retention storage is effective because it holds the runoff from the beginning of a storm, when urban pollutant washoff is the greatest. There are still many unanswered questions on precisely how effective retention storage can be based on such variables as: 1) size and solubility of the contaminants, 2) length of time for the contaminants to washoff the surface and 3) size, duration and intensity of the storm. These factors would need to be assessed to determined the size and cost of retention storage.

Street sweeping ranks behind retention storage in effectiveness as a water pollution mitigation measure. This pollution abating technique was simulated by reducing the total number of days of dust and dirt accumulation prior to the test storm from 20 to 10 days. Consequently, the model treats it exactly as a 50% reduction in total washoff and peak concentration of total suspended solids. The actual reduction in the total dust and dirt accumulation would depend on the characteristics of the sweeping processes. Present sweeper operations remove about 50% of the dust and dirt fraction of street contaminants. With multiple cleaning cycles of slower sweeping speeds efficiency can be improved to as high as 90% with present equipment. Thus, if the sweeping were conducted every five days and were operated at between 95 and 100 percent efficiency, its effectiveness would be twice that indicated in the sweeping simulation. It would thus approach the effectiveness of retention storage in improving water quality in many of the subareas. However, this extensive sweeping could be determined to be prohibitive from a cost effective standpoint.

Reduction of the impervious coverage for each urban land use type created an increase in the peak concentrations of total suspended solids in the rivers. This increase was due to a decrease in the amount of runoff available to dilute the pollutants washing off the land. The simulation assumed that the same amount of pollutants would wash off a given area of urban land use. These results show that a strategy of reducing the amount of impervious surface in an urban development is not enough by itself to improve water quality. A reduction of the amount of total suspended solids washing off this urban land is also required.

Though increasing the amount of surface for water absorption or detention decreases the volume of runoff available for dilution of pollutants, it can reduce peak flood flows. It can also be effective in recharging groundwater storage and contributing to higher stream base flow conditions from groundwater supplies during dry periods. Therefore, effort to provide more pervious surface, such as greater open space requirements, needs to be combined with efforts to either remove, retain or detain contaminants to present degradation of water quality in nearby streams.

Impact of Mitigation Measures on Air Quality

The motor vehicle emission control device requirements are the air quality mitigation measures studied in this report. Different levels of implementation of the emission device program were tested for their effectiveness.

The simulated effect of the emission devices on future levels of carbon monoxide provide dramatic results. In the Continuing Trends 478 alternative, the only alternative for which both the 1973 and 1990 vehicle emission factors were modelled, the results showed that when the 1990 factors were used, there was about a 30 to 40% decrease below the 1973 annual average carbon monoxide concentration in the urban areas and there are no violations of standards. With the 1973 factors, there was a 100 to 200% increase in the annual average CO concentrations over most of the urban portions of the County with up to 20 8-hour standard violations per year.

The results of this analysis point to the importance of an effective motor vehicle emission device program. The simulations indicate that the devices could keep the carbon monoxide levels below the federal eight hour standard for all land use patterns, even at the 630,000 population level. Although this condition will vary greatly from city to city based on their traffic pattern and population size, the finding does establish the importance of the motor vehicle emission device program relative to other methods for reducing carbon monoxide. In this case, the emission device provides a far more effective method than altering the spatial pattern of land uses.

POLICY IMPLICATIONS OF LINKAGES

The influence of the existing state, regional, and local policies on land use is described in Chapter Four. The descriptions indicate the wide variety of policies and enforcement actions that are presently being used in California. Most of these policies can have a direct or indirect influence on the future pattern of urbanization in a region. As was pointed out in Chapter Four, there is presently a lack of detailed knowledge as to which of the different agencies or policies has the greatest impact on guiding growth or whether other forces, including those more connected to the private market place such as housing preferance or land cost have a greater influence on urban spatial patterns.

However, if the various governmental agency policies were integrated based on a consistent set of planning objectives, and the private market were clearly guided by such a plan, then a particular growth pattern could be achieved that could result in the air and water quality patterns described by the earlier modeling analysis. Such a condition can more easily be understood when presented in the form of an example. For this purpose, appropriate policy actions have been determined for the Santa Rosa Centered land use pattern. This example was selected because it comes nearest ABAG's concept of a "city-centered" region. Table VII-3 provides a cross reference of the

policy actions required by the different state, regional, local and special district jurisdictions to create the Santa Rosa Centered pattern. Using Table VII-3, it is possible to draw a variety of conclusions on the implications of land use decisions on air and water quality based on the model findings.

The policy implications of the land use/air quality/water quality interrelationships can be categorized into 1) spatial form and assimilative capacity considerations, 2) mitigation measure considerations, and 3) governmental considerations.

Spatial Pattern and Assimilative Capacity Considerations

A number of important implications for policy planning emerged from the analysis of the impact of spatial form on air and water quality. First, both the air and water basins need to be described in terms of their capacity to assimilate or absorb air and water pollutants. Wind patterns, topographic features, upwind land uses and transportation patterns will be the major determinants to the concentration of oxidants in a sub-regional area. Watershed size, wet and dry weather flow, rainfall characteristics and channel shape are key features in describing the assimilative capacity of a river. The impact of population size, pattern of urbanization or land use activities on air and water quality can vary greatly according to the assimilative capacity of the subregional area. Therefore, a plan which intends to use growth management mechanisms, such as sizing of sewage collection and treatment system, to promote a particular land use pattern aimed at ensuring high air quality must first determine the level of growth that can be accommodated by the assimilative capacity of the sub-region. It is also possible that the air and water sub-regions have a substantially different capacity to accommodate additional population and employment. The Petaluma River, for example, can accommodate the treated effluent from an increased population but would have greater oxidant problems associated with growth due to its lower air pollutant assimilative capacity. Therefore, the policy implication is that assimilative capacity asssessment is an initial step in the environmental management planning process prior to subsequent decisions on location and timing of growth.

A second policy implication is that population and employment size should provide the essential link between air and water quality planning. Therefore, methods of population and employment forecasting, including those based on alternative policy actions, should be uniform for both air and water quality planning. With the assumptions clearly defined, the forecasted figures can then be translated into their influences on pollution creating activties and assessed against the assimilative capacity of a sub-region to determine appropriate levels of growth controls and/or types and amounts of required mitigation measures.

A third policy implication is that some compromise may be necessary to achieve optimum air quality, however defined. As was seen from the study, concentrations of reactive and non-reactive air pollutants are

TABLE VII-3

SANTA ROSA CENTERED GROWTH MANAGEMENT POLICIES

Description:

Regional:
- concentrated regional population
- concentrated regional employment
- high urban population
- highly centralized population within city
- highly centralized employment within city
- high population density within city
- high employment density within city

Air and Water Quality:
- highest CO concentrations
- highest particulate levels
- low County oxidant levels
- highest concentration of pollution in Santa Rosa streams
- no major difference at receiving waters

Agency	Policy Action	Possible Conflict
STATE		
Department of Transportation	- strong central transit support - region wide parking commuter constraints	- support to regional transit
Energy Resources Conservation and Development Commission	- approval on regional energy supply necessary for population expansion	- energy transmission to all parts of region
Office of Planning and Research	- limited policy influence	
Department of Fish and Game	- limited policy influence	- designating Santa Rosa River as of fish and game concern with attendant permit restrictions
State Water Resources Control Board	- approval of full funds for expanded STP capacity and appropriate collection system - designating minimum "beneficial uses" for urban waterways - active enforcement of hook-up restriction in other cities or rural areas when applicable - high priority rating for Santa Rosa STP	- approval of funds for over-sizing of STP and collection systems in other cities
Air Resources Board	- approve SIP and AQMP that supports city centered concept, even with short term potential of localized air pollution concentrations - approve a Parking Management and Indirect Source approach that provides flexibility for city centered facilities and greater restrictions for suburban and other cities projects	

Table VII-3 (con't)

REGIONAL

Agency	Policy Action	Possible Conflict
Association of Bay Area Governments	- develop 208 and AQMP's that emphasize city centered concept. - A-95, EIR's which support ABAG city centered concept consistent with regional plan	
Bay Area Air Pollution Control District	- flexible or non-restrictive point source review permitting continued employment expansion in Santa Rosa, even if some point sources may exceed some standards (e.g. particulate)	
Regional Water Quality Control Board	- develop Basin Plan establishing "beneficial uses" compatable with an urbanized Santa Rosa	- stringent and uniformly "remedial actions" in compliance applied to point sources that have disproportionate effects on Santa Rosa point discharge
	- hook-up restrictions in other parts of the County - stringent septic tank and cesspool restrictions in rural areas - flexibility in "remedial actions" to dischargers in Santa Rosa - expansion and quality improvement of SIP and collection system in Santa Rosa	
Metropolitan Transportation Commission	- approve funds for mass transit	- approve full regional highway network
	- approval of regional road system to support the Santa Rosa growth pattern - minimal approval of roadway network in Santa Rosa to curtail suburban growth	
Bay Area Sewage Services Agency	- no jurisdiction in Santa Rosa	- actions to facilitate disproportionate growth in Petaluma

Table VII-3 (con't)

LOCAL

Agency	Policy Action	Possible Conflict
City of Santa Rosa	- establish general plan policies favoring increased and compact growth	
	- enforce subdivision regulations, zoning, and permit issuance consistent with policies of compact growth in General Plan	
	- increase capacity of sewer and water services, but minimize spatial expansion	
	- design road network and traffic management program for increased population but sensitive to transit promoting techniques	
	- transit program expansion	
	- use density zoning regulations, including bonuses to achieve more dense, compact developments	
	- create urban renewal agencies to promote redevelopment and intensification of land use in city center	
	- use advance acquisition of land through eminent domain powers as a measure for redevelopment of downtown	
	- use growth sequence zoning through timing permits to prevent urban sprawl	
	- nonconforming use regulations to eliminate or prevent expansion of uses which are in conflict with planning and zoning for compact, dense growth	
	- continue stringent limitations on lot splits	
	- use agricultural zoning to confine urban development	
	- acquisition of full or less-than-full interest in land to preserve open space surrounding city to encourage compact growth	- too great an effort to force compact pattern may discourage residential and commercial growth away from Santa Rosa

Table VII-3 (con't)

Agency	Policy Action	Possible Conflict
Other Cities and County	- general plan policies favoring limited growth	
	- enforce regulations and ordinances consistent with General Plans	
	- limit sewer expansion	
	- limit expansion of road networks	
	- support intra-regional transit program	
	- stringent County limitations on lot splits	
	- agricultural zoning to encourage urban development in Santa Rosa	
	- acquisition of full or less-than-full interest in land to preserve open space surrounding city to encourage compact growth	- too great an effort to force a compact pattern may discourage residential and commercial growth away from Santa Rosa

Table VII-3 (con't)

SPECIAL DISTRICTS

Agency	Policy Action	Possible Action
Local Agency Formation Commission	- limit annexation in Santa Rosa to permit total population increase but still restrict sprawl and thereby support high density development - restrict annexations in other cities - limit formation of special districts when they are population and employment inducing	- annexation restrictions limiting high density development
Sanitation Districts	- limit size of collection and treatment facilities in all areas outside Santa Rosa - prohibit septic tanks and cesspools in rural areas - establish sewer "hook-up" restrictions	
County Water District	- limit size of sewage collection and treatment facilities in all areas outside Santa Rosa - design water distribution system to achieve population and employment in Santa Rosa and not in the other cities	
Resource Conservation Districts	- limited influence	

dispersed in dissimilar patterns. A population dispersed through the region may create the lowest CO concentrations but produce an increased oxidant problem in a particularly sensitive area. Therefore, it is necessary to study each air contaminant separately and base land use recommendations on a priority ranking of individual air quality standard achievement and maintenance.

A fourth policy implication concerns the conjecture that centralized and compact urban development is always the best spatial pattern for meeting the objective of minimizing air pollution. There is a risk in developing a compact urbanization pattern on the assumption that it will facilitate a lower dependence on the car and a higher use of mass transit. The study demonstrates that highly centralized and dense spatial forms, that are auto-dependent, will result in the highest CO and particulate levels of any of the land use patterns. This is due to the concentration of car use in a small area where the combination of a high number of cars and the confined road network result in congestion and high localized production of contaminants. This air pollution condition means that there is a greater need for adopting adequate levels of mitigation measures including mass transit and parking limitations. Inadequate political or economic support for such measures would mean that the long-term commitment to the compact development could well include the long lasting existence of high population exposure to certain air contaminants. The centralized spatial pattern presents a potential risk situation unless air quality planning is closely related to land use and transportation planning decisions that will mitigate the undersirable impacts associated with compact growth.

Unfortunately, the policy implications of centralized versus dispersed development receive contradictory and somewhat ambivalent treatment in the present air quality regulations. As indicated by the Santa Rosa Centered policy actions required by the Air Resources Board and BAAPCD (Table VII-3), some flexibility in regulation administration may be required if new businesses or apartments are to be permitted in the core of Santa Rosa. A new office complex would not want to locate in the downtown if it knew "indirect source" requirements would restrict its parking while permitting offices located outside the downtown, where the air is cleaner to have more parking. Either a more lenient position on downtown parking or strict parking limitations on suburban office zoning would be needed to attract and protect centralized offices.

Mitigation Measure Considerations

A second category of policy implications is that associated with the use of mitigation measures for minimizing air or water pollution. Perhaps the most significant policy implication is that mitigation measures, particularly those associated with stormwater runoff, provide far more effective methods of pollution abatement than the control of spatial form.

This policy implication is important to federal, state and local levels of government. To the Environmental Protection Agency, it highlights the need for further study on the usefulness and limitations of the different measures. Information concerning implemen-

tation of the measures including cost, staffing expertise, and legal constraints are of particular importance for study. To the state's regional water quality control boards, its importance relates to the funding implications related to both existing sewage treatment grants and possible future assistance in creating retention storage. For local government, the significance of the mitigation measures is both how they can be used in new development conditions and the financial and legal implications of implementing them.

There are a variety of unanswered questions about the effectiveness of the different devices to reduce surface runoff water pollution. The aspects of retention storage requiring further study include:

1) ways to build retention storage into presently developed areas

2) application of different retention measures for different land uses

3) methods for determining the most cost effective sizing of detention storage facilities

4) costs and legal implications of cleaning and maintaining retention facilities following storms

5) treatment versus discharge of retained stormwater.

Street sweeping, although generally more straightforward than retention storage, can also benefit from further study. The review of literature in this report discussed the previous research on street sweeping. One dimension that the earlier research did not cover is optimum sweeping patterns or frequencies within different cost levels. For example, a commercial area, with its higher pollutant loading and higher percentage impervious surface coverage, may require extremely frequent sweeping during the rainy season. Sweeping in residential areas, on the other hand, might have a cost effective pattern of infrequent sweeping except just prior to the first storm in the wet season.

Cities and counties should also consider the implications of street sweeping to the creation of special districts. If a particular area, such as an industrial park, is anticipated to have a higher pollutant washoff rate, it may be appropriate to create a special assessment district for that area to provide for the costs related to a greater frequency of sweeping.

General Governmental Considerations

A third category of policy implications from this linkage finding is concerned with the need for improved governmental policy setting. None of the implications that will be discussed will be particularly new or startling. The importance in listing them is that they be recognized in preparing planning strategies and openly addressed in the developing of an environmental management strategy.

First, the orchestration of a proper mix of land use policies to achieve specific spatial patterns or mitigation measures presents a major challenge. The Santa Rosa Centered example given in Table VII-3 lists some 55 policy actions necessary to be adopted and implemented by the various state, regional and local jurisdictions to encourage a spatial pattern for environmental enhancement. These actions do not reflect the many other possible policy implications emanating from housing, flood control, historic preservation, economic development or seismic safety requirements. The importance of this implication is that policy must be integrated into the far broader issues of urban and regional development to achieve a regionwide strategy for environmental management.

Second, some policy flexibility is required if compromises are to be made in environmental planning. As pointed out earlier, air quality policies may require some modification if a particular spatial pattern is desired as part of a long-term strategy. Localized pockets of CO or particulate concentrations may have to be accepted to achieve broader regional air quality objectives. Individual land use decisions in the localized areas must recognize this constraint and accept it as a viable policy approach.

An acceptable tradeoff in a regional water quality strategy might allow a particular segment of a stream or river to have higher amounts of pollutants than desired for the entire river while still protecting the beneficial uses in other sections of the river. The strict enforcement of a non-degradation policy could be counter-productive to this overall approach and may need some interpretive flexibility in its implementation.

The importance of this policy implication is that it is far better to recognize the need and set limits on flexibility at the outset of planning rather than ignore the need or permit it to be applied through a potentially more erratic appeal or judicial process.

Third, growth control strategies at a regional level may require a two-sided approach of encouraging new development in one area while constraining it in others. Such an approach will require the resolving of many contradictory issues involving both environmental quality and political and economic equity. An example of a dichotomous situation exists in the Valley of the Moon where the collection and sewage treatment capacity of areas planned for minimal growth is being expanded and extended to get the existing homes off the use of septic tanks. In this example, a growth and environmental management mechanism, the sewer system, can be working at cross-purposes. It can improve the environment by reducing the dependence on the water polluting septic tanks. Yet, it will provide the basic infrastructure by which further population growth can eventually be permitted, thereby increasing the potential for reduced air quality.

Similarly, a rural section of the county may have a bus service extended to it which could reduce the dependence on the car but also make the area more accessible for further residential expansion.

The policy issue that these linkages highlight is one of balancing the need for a basic level of governmental services throughout the region against the growth inducing effects of these services. The debate will become particularly difficult when an area totally lacks the basic services such as the above example in the Valley of the Moon.

The resolution of the issue needs to be made at both a local and regional level based on a debate on the type and quantity of the service, the specific demands it is trying to satisfy, and the extent of potential environmental damage that may result should the costs of population inducement outweigh the benefits of the particular service. This form of assessment should guide the policy makers by providing an evaluation system that highlights the trade-offs.

The policy implications from the findings on linkages between land use/air quality/water quality should provide real assistance to those jurisdictions that are preparing to undertake environmental management planning efforts. The conclusions on spatial form and assimilative capacity indicate some direction in which initial regionwide planning studies could be pointed. The effectiveness, and therefore importance, of mitigation measures should encourage local jurisdictions to look further into the more detailed issues of how the measures might be carried out. The governmental implications are more complex and potentially most elusive. Chapter Eight contains a number of recommendations on the manner by which some of these policy implications could be addressed.

CHAPTER VIII - RECOMMENDATIONS FOR AN ENVIRONMENTAL MANAGEMENT STRUCTURE

The conclusions of Chapter VII suggest that land use controls can be used as part of an overall plan for achieving desired air and water quality objectives. The section on the deficiencies of the pollution control structure provided in Chapter IV indicates that a new direction is necessary in the application of land use controls through a more integrated and effective environmental management program. The primary problem of the present structure as it relates to the use of land use control measures to reduce environmental pollution is that there is the lack of an adequate role for local government. The efforts that EPA has made to employ land use related factors in individual environmental management programs (e.g., parking management, indirect source review, sewage treatment sizing based on environmental impacts) have emphasized controls to be imposed by state and regional levels of government. The failure of these measures to win acceptance can be partially attributed to the lack of effective involvement with the land use planning process at the city and county level. This chapter will suggest strategies for improving governmental sensitivity to environmental needs. Further study will be required to provide further elaboration on the proposed measures.

If land use measures are to be successfully used to support air and water quality objectives, a structure for environmental management has to be devised that connects the intent, concerns and funding of the federal and state programs with the institutions and the expertise for comprehensive land use planning and control that already exists at the local level. The potential advantages of an approach that involves local government are that it makes use of administrative organizations, powers and implementation devices that already exist, thereby avoiding duplication and the imposition of additional administrative and enforcement procedures. It has the important added advantage of relating the achievement of air and water quality to the attainment of other community objectives, thus permitting appropriate tradeoffs to be made and a determination of the most publicly acceptable implementation strategies.

BASIC REQUIREMENTS FOR AN ENVIRONMENTAL MANAGEMENT PLANNING PROCESS

The overview of the present pollution control system highlights five basic deficiencies that need to be remedied. When restated as necessary components of a regional environmental management plan, the five are:

1) integration of air and water policies and actions with other functional elements required in comprehensive planning, e.g. transportation, conservation of natural resources, housing, urban design, agriculture,

2) integration and consistency of the policies and actions by the different governmental agencies that influence air and water quality,

mechanisms. The design review procedures provide specialized considerations for selected land uses or locations. Implementation or enforcement measures including conditions to zoning or performance standards provide wide administrative flexibility to ensure mitigation measures or growth management considerations are implemented. The principle element local government lacks is a regional perspective on the impact of the pollution generated within its boundaries on other cities or counties in its region. When this perspective can be provided in a regional environmental planning framework, local government can direct its established planning and enforcement ability to carry out both local and regional air and water quality objectives.

Cities in the study area like Santa Rosa or Petaluma have sufficient staff capability to conduct or direct planning studies aimed at developing a set of air or water quality policies. However, the smaller municipalities would have difficulty in preparing sophisticated environmental approaches. Similarly, the new enforcement review methods that require a considerable knowledge of air or water pollution impacts are presently beyond the expertise of the staff in smaller cities. Therefore, state and regional planning agencies must provide an administrative alternative for these small cities. Staff and/or financial assistance for providing the local approaches could need to be available.

Local planning agency staff tranining programs in air and water quality planning and enforcement are necessary. Experience of local administrators may indicate that a state certification program, similar to that for sanitary engineers in the local public health departments, is necessary and desireable to ensure competence in implementing the control measures.

<u>Creation of a Consistent Review or Appeal System</u>. As stated earlier, the main improvement needed in the review or appeal process is assurance that the review decision is consistent with the intent of the environmental planning policies. There are presently two levels of review. The first is that which occurs when a general plan or a functional plan (e.g., transportation plan, water quality plan) is developed. This review needs to provide a check to ensure that a plan prepared by a local jurisdiction is consistent with the plan of a regional or state agency. For example, a circulation element prepared for a local government general plan would be reviewed by the regional transportation agency for consistency with regional transportation objectives. Quantitative measures of the anticipated effectiveness of the different local transportation strategies and a program of implementing the strategies including capital or operating expenditures would need to be provided.

At present, the environmental impact report review requirements attempt to provide for this form of review. Yet, the deficiencies of the EIRs point to the need to place some sanctions against those plans that are inconsistent with local, regional and state comprehensive plans. For example, a local air quality control approach that is not consistent with the regional strategy would not be delegated indirect source review powers.

The second level of review is that for individual capital works projects or individual land use changes, e.g., zoning, subdivision approvals. This level presently has the greatest number of different reviews, including those made by zoning appeal boards, A-95 reviews, regional and State regulatory agencies and, potentially, the court. Consequently, the decisions made by these various bodies have the greatest opportunity for divergence or inconsistency. For example, a lenient decision by an air pollution hearing board that permits an industry to locate at a particular site may not be viewed by either a zoning appeals board or the court as consistent with the general plan policies. Similarly, a regional water quality control board or sewage service agency may approve the size or configuration of a sewage collection and treatment system that is inconsistent with the growth objectives of regional or local comprehensive plans.

This second level of review requires more focus as to what the zoning appeal or project is being judged against. Is it consistency with a general plan's policies as in the case of a zoning or subdivision court case? Is it the secondary growth impacts of a "201" treatment facility? Is it the regional air quality strategy that tolerates localized concentrations of CO or a State air quality program that does not permit such concentrations?

The answer to these questions lies in the development of integrated environmental management plan that provides for consist inter-governmental policy setting. Such a plan should provide policy guidance on matters of growth inducement or location of dischargers. The plan therefore would provide the basis for an appeal judgment on consistency between the environmental policies and the individual project. If environmental management plans successfully integrate other functional elements and local general plans are made consistent with regional plans, then there would exist a body of local government policy that provides for treatment of land use and capital budgeting decisions that is uniform with the state and regional environmental strategies.

For example, a regional environmental planning program would:

1) establish the beneficial uses -- i.e., protect shellfish beds

2) establish standards for the protection of beneficial uses, or procedures necessary to determine such -- i.e., measurements in both concentrations and sedimentation levels for different contaminants necessary to protect the shellfish

3) establish the potential control methods to reach the standards -- i.e., street sweeping, retention storage, in-system storage and treatment

4) establish which jurisdiction would be most necessary and most effective in implementing the control for a particular beneficial use

Both the regional and local agencies would assess the various control methods for 1) their relative ability to achieve the standard, 2) their financial and institutional consequences and 3) their impacts on other functional elements such as land use and housing. For example the cost of a control method like retention storage, which might be passed on to new residential development, would need to be assessed against the objectives of regional and local housing element. Once both the local and regional assessment is completed and the necessary compromises and alterations are made, the local government would adopt the water pollution control strategy as an amendment to their general plan. The local agency would then develop or amend the various ordinances to provide the implementation methods to carry out the strategy.

The next step would be to ensure that implementation actions are consistent with the policies. The existing general plan legislation, providing for court review of consistent planning policy enforcement, provides a useful model for an improved appeal process. First, the purpose of the review is very explicit -- determination of consistency. Secondly, the court review encompasses the entirety of all elements of the general plan rather than the limited scope of a single function hearing board. (It should again be pointed out that the breadth of the court review is not yet firmly established as to whether it includes the consistency of the act of rezoning or, more restrictively, the consistency of zoning maps to general plan maps.)

The determination of consistency requires judgment on a case-by-case basis. Such judgment would be based on the intent of the policies. It requires clarity of planning objectives, including priority of one objectives over another. For example, a central city may want to manage its downtown parking in such a manner as to discourage peak hour commuter traffic as part of its effort to improve air quality. Yet, it may want to permit some additional retail parking as an effort to keep its downtown economically viable. This priority of one form of parking over another would need to be clearly established in the transportation policies. Then, a new downtown building, whose zoning permit did not include parking management conditions (e.g., proportionally higher fee after the first two hours, opening the lot after 10 a.m.) could be challenged as inconsistent with the general plan transportation policies.

The major drawback of the court review system is that it can be expensive and create a new burden on the judicial system. Therefore, new forms of appeals need to be considered such as semi-judicial appointed appeal tribunals at the regional or sub-regional level. Such tribunals could be empowered to review appeals made by residents or property owners on local or regional decisions as to their consistency with the planning policies. The tribunals would concern themselves with the <u>content</u> or <u>substance</u> of the consistency issues (e.g., the intent of the policy) while the court would continue its role in judging if the <u>process</u> by which the content was evaluated was equitable.

Adoption of Clear and Specific Policies. The adoption of clear and specific planning policies becomes critically important when enforcement actions are legally required to be consistent with policies. The present condition in some municipalities of vague policies combined with highly discretionary enforcement mechanisms can lead to frequent challenges on consistency. Instead, jurisdictions need to adopt explicit statements of air and water policies whose impacts are capable of being measured. As an example, policies that require retention storage should indicate the relative quantity of water runoff that the new development should retain. Similarly, management policies should be based on specific range of population or employment size assumptions for the future and indicate the conditions under which this growth would occur. A regional plan may determine that the assimilative capacity of a watershed could permit a combined work force and resident population of 100,000 people in a particular basin given the existing level of sewage treatment and methods to reduce surface runoff. However, it could accommodate an additional 50,000 if retention storage were required in all new development, the capacity of the treatment facility was expanded and more frequent and effective street sweeping were undertaken. All three of these measures should be explicitly stated as policies and assumptions and tested for their impact in achieving regional and local environmental objectives.

Clear Assignment of Responsibilities. Each of the governmental entities involved in air and water quality planning should be given a clear responsibility for specific aspects of plan preparation, plan review or appeal and plan enforcement. Such clarity in assignment is necessary to ensure that all environmental management issues are treated in a comprehensive, systematic manner and that the public has a better understanding of whom they must deal with on matters of new development or in appealing recent decisions. Implied in the need for a clearer assignment is the elimination of duplicative planning or plan enforcement.

The nature of the assignment of responsibilities should be related to the agency's perspective and abilities. For example, it would be appropriate for a regional agency to determine the assimilative capacity of each watershed in the region and determine the cause and effect relationships of pollutants that travel across multi-jurisdiction boundaries. It would then be the responsibility of the local jurisdiction to develop alternative management approaches to prevent the assimilative capacity in a particular area from being exceeded. The final section of this chapter will outline the responsibilities of jurisdiction levels in developing and enforcing an environmental management plan.

INTERGOVERNMENTAL RESPONSIBILITIES IN PREPARING AN ENVIRONMENTAL MANAGEMENT PLAN

The question of the appropriate governmental framework to provide for the required environmental analysis, policy setting and implementation raises some complex issues. The framework must be adjusted to the

existing governmental institutions in the particular state and region and the state and local laws that guide land use and environmental planning. It is therefore difficult in this study to specify a detailed institutional framework that would fit the needs of all areas in the country. Therefore, the following recommendations will present a generalized outline of the different jurisdictional levels concerned with environmental planning and enforcement and will relate most specifically to California and the San Francisco Bay region. The recommendations may appear to be less useful to those states whose regional or local planning laws and institutions are not as strong or complex as those in California. The state authorities may have to play a more direct role in both the planning and enforcement of environmental management controls. However, the importance of the recommendations is that it highlights the components of a cooperative approach between the different levels of government in preparing the plans and it provides the beginning of a more direct role that local government can play in environmental management.

State Environmental Planning Requirements

The existing environmental management planning responsibilities of the various State agencies provide for an effective planning program. The only significant change required at the State level is a better system for integrating their policies into a more cohesive set of State comprehensive planning objectives. The improvement most needed in the area of state level enforcement of environmental objectives is the delegation of some permit issuance to the local level when proper assurances can be made that state objectives will be effectively implemented.

Planning Requirements. The existing State level planning responsibilities have been discussed earlier and should continue to include:

1) making State plans consistent with federal environmental objectives,

2) establishing more stringent State objectives when the existing environmental conditions warrant it,

3) integrating with other State functional elements,

4) monitoring and evaluating the effectiveness of State and regional policies, and

5) establishing State and regional financial assistance priorities in line with state objectives.

The State planning responsibility that requires the greatest attention is the integration of the planning efforts of the various state agencies. The chapter on the existing State governmental structure indicates the substantial influence the State Water Resources Control Board has in

determining growth within a region. Similarly, the Department of Transportation and Energy Resources Conservation and Development Commission have a strong control on the location, size and timing of basic regional service infrastructure. The method by which the infrastructure decisions are made or state financial priorities are set requires a more comprehensive approach. This comprehensive planning approach must provide guidance to regional and local government on the earlier discussed issue of a basic level of governmental services throughout the state versus the growth inducing effects of those services. It must also provide the methods to resolve governmental conflict when intra or inter-governmental policies work at cross-purposes.

Plan Review and Enforcement Requirements. The existing roles of state agencies in the review and enforcement of air and water quality planning objectives include: 1) establishing ambient air or water quality standards, 2) establishing emission levels from point and mobile sources, 3) setting expenditure priorities, 4) approving plans and projects and 5) replacing or voiding the actions of regional, single, purpose boards (e.g. air pollution control districts, regional water quality control boards). In contrast to these enforcement powers is the review authority of the Department of Fish and Game which reviews and issues permits on individual development actions that take place on or in a water body. It is this form of policy enforcement that is duplicative of local policies and enforcement controls. This is a case where local planning policies could be made consistent with the policies of the California Fish and Wildlife Plan and the State enforcement powers delegated to local government when there are adequate guarantees of local staff capability. Direct state involvement on local development decisions should be avoided unless the subject matter is so complex that only a specialized form of administrative expertise is required.

Regional Environmental Planning Responsibilities

The regional responsibilities in environmental management planning are to provide regional direction to state and federal objectives and to describe the role local government should play in planning and enforcing air and water quality objectives.

Planning Requirements. There are nine planning requirements that regional governmental agencies should undertake:

1) making plans consistent with federal and state environmental objectives,

2) integrating with other regional, functional plans,

3) establishing more stringent regulations than those of the federal or state government if existing environmental conditions warrant them,

4) setting regional financial priorities on the use of state and federal assistance,

5) monitoring the environmental conditions in evaluating the effectiveness of planning policies,

6) describing the assimilative capacity of the region's sub-basins

7) identifying population and employment level assumptions per sub-basin in line with assimilative capacity,

8) describing of the land use control or capital expenditure options available for local government, and

9) describing the regionwide spatial patterns of development that might provide optimal air quality conditions.

The first five of these responsibilities need little explanation in that they have been discussed above. The remaining responsibilities do require some description.

A major means of meshing air and water quality planning is through the allocation of future population and employment levels that can be accommodated within the environmental quality standards established by the federal and state legislation. The central task of this requirement would be the indentification of each of the region's air basins and watersheds and the evaluation of their assimilative capacity.

Beside establishing the general ranges of population and employment appropriate for analysis at each sub-region, the regional body should establish environmental performance criteria for each sub-region. The performance standards would reflect acceptable levels of pollution that could be emitted from a particular area. These pollution levels would be associated with both locally and regionally established beneficial uses that are to be protected. Implied in the setting of performance criteria is that pollutant emissions could be variable, based on the nature of activities that are desired near the emission sources and the related consequences of such contaminants on other sections of the region. For example, the total suspended solids concentrations running off into the Petaluma River may be very low when measured in nearby water permitting a wide variety of activities at that point in the river. However, the total emissions or washoff may have a considerable impact on the crab beds 15 kilometers downstream where the emissions reach the receiving waters and finally settle. As a consequence, more stringent runoff measures would be required in the City of Petaluma for the purpose of protecting regionally designated beneficial uses. Therefore, the performance standards must reflect 1) the concentrations of pollutants that can be tolerated by the population in nearby areas and 2) the total emissions that will be transported and impact other areas in the region.

These standards could be expressed both as ambient levels of pollution that should not be exceeded and as effluent or emission limits for the various types of pollutants which can be discharged into the air and water of the sub-region during a given time period.

The primary utility of these standards, besides providing a means of measuring goal achievement, would be to suggest to local government the types of policy actions they could take to reduce the impacts of existing or new development. For example, in an area with a severe limit on the amount of total suspended solids permitted to enter local water courses, local government would have to take steps to limit the pollutant loadings carried by urban runoff. A variety of means are available to do this and it would be up to the local government to choose those methods that would be most appropriate for its particular circumstances. The regional body could develop an assistance program to provide local governments with the specialized information and expertise necessary to evaluate alternatives.

As pointed out earlier, establishing a particular regional or citywide spatial pattern to attain optimal air quality conditions presents some perplexing issues. The modeling analysis projects that concentrated residential and commercial development can lead to the worst alternative in terms of population exposed to air quality conditions exceeding the governmental standards. On the other hand, a concentrated pattern is thought to be the best pattern for encouraging the use of mass transit and the disuse of the car. This theory is based on the premise that concentrated land use patterns 1) can make transit routes more available to a large number of people and 2) facilitate shorter trips between home and work or shopping facilities. The importance of shorter trip lengths is currently being questioned as to its importance to air quality.

Unfortunately, the usefulness of the Sonoma Study is that it raises questions on spatial pattern and air pollution that needs further study and debate rather than provides conclusive evidence as to the best spatial land use strategy.

Regional Review and Enforcement Requirements. The existing methods for enforcing air and water measures at the regional level, including 1) issuance of discharge permits for sewage treatment plants or industries, 2) air pollutant emission permits for stationary sources, 3) sewer hook-up moratoria 4) plan and project review by various regional agencies, and 5) assistance in setting budget priorities provide sufficient means of ensuring environmental quality.

Their main inadequacies are those discussed earlier including the lack of integration and consistency of air and water quality objectives with those of other agencies. Regional governmental agencies can improve on the administration of these measures through a more focussed review of plans and projects. The plan review can be directed through the same mechanisms - e.g. A-95 reviews, environmental impact report reviews - but greater attention needs to be placed on reviewing for consistency of local plans and projects with regional objectives.

The regional level of government can play a new role in environmental management by providing an improved system of appeals to local and regional decisions that are challenged as being inconsistent with regional and local plans. A series of regional or sub-regional appeal tribunals could relieve the court system of the potential burden of determining planning implementation consistency. The tribunals could also ensure that the actions of separate local or regional boards were reviewed as a part of a whole rather than as separate or unrelated events as is presently the case with the existing appeal boards.

Local Responsibilities

The basic role of local government, including cities and counties, is the preparation of local planning approaches to implement the regional and local environmental management strategies and to use their varied land use controls powers and expenditure programs to carry out their approaches.

Local Planning Requirements. Local planning departments and commissions would be guided by the regionally determined population and employment range assumptions and environmental performance criteria in preparing their individualized approaches to attaining and maintaining air and water quality objectives. Their planning would require local-scale analysis of the air and water quality impacts of specific plans and projects, with an emphasis on identifying the most appropriate mitigating measures. The local plans could enable higher population or employment objectives if their approaches indicated a willingness and capability of undertaking higher degrees of mitigation measures or spatial organization to reduce pollution emission. Higher treatment levels at the sewage treatment plants, increased bus service or shifting of housing or office densities to promote the use of mass transit are such measures.

Local Enforcement Requirements. The local governmental units could be encouraged or required to adopt ordinances and other plan implementation control mechanisms that incorporate a combination of development guidance and mitigation measures that would ensure compliance with the performance standards set by the regional body.

In order to induce the local government to adopt the enforcement devices, greater autonomy in air and water quality related matters could be delegated. For example, those governments that adopt plans and ordinances that are consistent with the regional strategy could have regional review or permit requirements waived or reduced for some classes of projects. They would also receive quicker or higher priority use of state and federal assistance.

This increased role of local government in environmental planning will place an added burden on existing staffs and budgets. To some cities or counties, the additional costs will be worthwhile in that they will ensure some local autonomy in policy planning and decision making. Other municipalities may find that the added costs are prohibitive and

the regional agencies will need to provide an alternative for this situation. Regional staff assistance and simplified policy and ordinance packages should be available in such circumstances.

SUMMARY

The recommendations contained in this chapter provide the basis for the more detailed organization that is required in preparing a regional environmental management plan and in establishing the governmental structure for its implementation. Arrangements among different departments or jurisdictions require a highly individualized approach based on the nature of the existing institutions. The logic behind each of the recommendations may require more localized and extensive justification to convince the policy makers of their rationale.

The findings and recommendations of the Sonoma Study are timely in that they can assist regional planning agencies in directing their present air quality maintenance and "208" planning efforts.

The conclusions on the linkages of land use, air quality and water quality demonstrate that there are some mutual influences. Air and water quality objectives need to be integrated through land use controls by an environmental management strategy. Yet, the linkages are less complex than initially anticipated and the influences of other regional or community objectives such as transportation requirements, housing preferences, energy conservation or agricultural protection may play a more significant role in deciding the nature of compromises that are necessary in developing the environmental management plan.

Consequently, the governmental structure elements of a plan may require considerably more attention than the selection of the proper urbanization pattern or mitigation measure. Added emphasis given to developing institutional cooperation will be an important key in the success of developing an integrated environmental management program.

APPENDIX A

Glossary

APPENDIX A - GLOSSARY

air quality standard - The maximum concentration of a specified air pollutant averaged over a specified time period (e.g., one hour, eight hours, one day, a year) that may not be legally exceeded.

ambient air - That portion of the atmosphere, external to buildings, to which the general public has access.

average daily traffic (ADT) - A term used to describe the average number of vehicles passing a specified point on a roadway during a 24-hour period.

basic employment - Employment in industries that produce goods and services mainly for export out of the County. In this study basic employment includes agriculture, forestry, fisheries, mining; industrial - manufacturing, long distance transportation and wholesale trade; and office - insurance carriers, holding companies, business services and large Federal and State installations.

biochemical oxygen demand (BOD) - A measure of the consumption of dissolved oxygen in water by the oxidation of organic materials. In general terms, a high BOD suggests a water burdened with organic wastes and thus likely to be deficient in oxygen and inhospitable for most plant and animal life.

biostimulation - A water quality condition that promotes the growth of aquatic plants.

carbon monoxide (CO) - A colorless, odorless, toxic gas produced by the incomplete combustion of carbon-containing substances. One of the major air pollutants, it is emitted in large quantities in the exhaust of gasoline-powered vehicles.

central business district (CBD) - The primary center of economic activity in a city; usually considered the "downtown" area.

coliforms - A large and varied group of bacteria. Fecal coliform bacteria, commonly found in the intestines and feces of warm blooded animals (including man), apparently does not cause disease, but its presence in water suggests that disease causing organisms may be present. Coliforms are used as indicators of pollution because they are abundant and their presense is fairly easy to detect.

dissolved oxygen (DO) - The concentration of oxygen dissolved in water (measured in mg/l). Non-living organic matter and various chemicals react with oxygen in water, depleting its concentration and causing stress (from lack of oxygen) on fish and other aquatic life. DO saturation levels are greater in cold water than in warm, and at sea level (high atmospheric pressure) than at high altitudes (low atmospheric pressure).

effluent - The liquid discharged by a sewage treatment plant or industry.

emission factor - An estimate of the amount of a specified air pollutant emitted from a source per unit time, or per unit of fuel consumed, per unit of distance traveled (e.g., grams of CO per mile) or per some other unit.

eutrophication - The condition in which a body of water is rich in dissolved nutrients, frequently leading to the proliferation of algal growth.

groundwater recharge area - The portion of a land surface through which the groundwater receives its replenishment by the percolation of water through the soil and intermediate zone.

groundwater - Subsurface water that fully saturates the pore spaces of the rock in which it is located.

heavy metals - Metals that can be precipitated by hydrogen sulfide in acid solution. For example, lead, silver, gold, mercury, and copper.

hectare - A metric unit of area equal to 10,000 square meters (.01 square kilometers, or 2.47 acres).

hydrocarbon - Any of a class of compounds containing only carbon and hydrogen in various combinations, found especially in fossil fuels. Some of the hydrocarbon compounds are major air pollutants. They may be active participants in the photochemical process. They also may be carcinogenic.

hydrograph - A graph of the flow in a stream during the time period of a rainstorm.

hyetograph - A graph of rainfall intensity versus time during the period of a storm.

inversion - The atmospheric condition in which a layer of warm air overlays a layer of cooler air, thus preventing contaminants in the bottom layer from dispersing into the upper air layer.

isopleth - A line on a map connecting points of equal value (e.g., an equi-pollution contour).

leach field - A system of open pipes within covered trenches allowing the effluent from a septic tank to enter the surrounding soil.

link - A specified stretch of roadway (e.g., U. S. 101 from Todd Road to Hearn Avenue).

link loading - The average number of vehicles per day on a link of a transportation network.

local-serving employment - Employment in those businesses that serve the population. In this study, local-serving employment includes retail trade and services; local finance, insurance and real estate; local government; and construction, transportation, communication and utilities.

low flow - The period, during the course of a year, when the flow in a stream is at a minimum. In California, low flow usually occurs in late summer or early fall, at the end of the dry season.

NH_3 - Ammonia (see "total nitrogen").

NH_3-N - The amount of ammonia expressed as equivalent nitrogen.

NO_2^- - Nitrite (see "total nitrogen").

NO_2^--N - The amount of nitrite expressed as equivalent nitrogen.

NO_3^- - Nitrate (see "total nitrogen").

NO_3^-N - The amount of nitrate expressed as equivalent nitrogen.

nonpoint source (air pollution) - A term used to describe air pollutant emissions from groups of minor stationary sources, such as furnaces in private homes and small commercial establishments. Also referred to as "area source."

nonpoint source (water pollution) - A term used to describe the contribution of water pollutants from sources that do not emanate from pipes or other man-made conduits. Examples of non-point sources are runoff from agricultural land, runoff from urbanized land and runoff from slopes that have been logged.

non-settleable solids - That matter in wastewater that will stay in suspension during a pre-selected settling period.

nutrients - Substances or ingredients essential to biological growth.

oxidant - A major air pollutant, primarily consisting of ozone with small quantities of nitrogen dioxide and peroxyacetylnitrate (PAN), formed by a photochemical process between hydrocarbons and oxides of nitrogen..

particulates - Particles of solid or liquid matter, usually suspended in the air: dust, soot, ashes, aerosols, mists.

photochemical process - The chemical changes brought about by the radiant energy of the sun acting on various polluting substances in the atmosphere; the process by which oxidant is created.

PO_4 - Orthophosphate, a hydrolyzed form of inorganic phosphate (see "total phosphorus").

PO_4-P - The amount of orthophosphate expressed as equivalent phosphorus.

point source - A discrete place of object (such as a smokestack or outfall from a sewage treatment plant) from which relatively large quantities of air or water pollutants are emitted.

pollutant loading - An estimation of the amount of a given pollutant washing off a land surface of a given type, usually after a rainfall.

primary treatment - A series of mechanical treatment processes, including screening, skimming and sedimentation, that remove most of the floating and suspended solids found in sewage, but that have a limited effect on colloidal and dissolved material.

reach - A stream segment, used in the model QUAL-II, comprised of several elements with homogeneous hydraulic properties.

receiving water - A natural watercourse, lake or ocean into which treated or untreated wastewater is discharged.

recession limb - The falling portion of a hydrograph in which water is being withdrawn from storage in the drainage area.

recurrence interval - A term referring to the frequency and intensity of storm. A storm with a 100-year recurrence interval has a 1% chance of occurring in any given year.

retention storage - The temporary storage of stormwater runoff in a device such as a pond or basin.

secondary treatment - A series of biochemical (trickling filters or activated sludge), chemical (coagulation), and/or mechanical (sedimentation) treatment processes, that remove, oxidize, or stabilize non-settleable, colloidal and dissolved organic materials found in sewage, following primary treatment.

stationary source - A non-vehicular source of air pollutants, such as a smokestack or chimney.

sub-area - A watershed of a small stream or creek or a portion thereof; the smallest unit of analysis in water modeling, defined using the criteria of homogeneous slope, homogeneous land use (hydraulic roughness), and uniform width, measured perpendicular to the direction of flow.

sulfur oxides - Pungent, colorless gases formed primarily by the combustion of fossil fuels. Considered major air pollutants, they may damage the respiratory tract as well as vegetation.

tertiary treatment - Any sewage purification process that has the capability to remove over 98 percent of the pollutants from sewage, following secondary treatment.

total nitrogen - The total amount of the element nitrogen, a principal nutrient required for biological growth, in all its chemical forms. Four forms of nitrogen are of main interest in water quality management. These are ammonia, nitrite, nitrate, and various compounds of organically-bound nitrogen. These forms are all normalized and expressed as total nitrogen.

total phosphorus - The total amount of the element phosphorus, a principal nutrient required for biological growth, in all its chemical forms. Phosphorus may exist in wastewater as ortho, poly, and organic phosphorus.

total suspended solids - All particulate matter in a water sample that is removable by laboratory filtering.

vehicle kilometers traveled (VKT) - A measure of the total amount of motor vehicle usage on a specified stretch of roadway or in a specified area (the metric equivalent of VMT).

"201" - Refers to Section 201 of the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500). Section 201 calls for detailed planning for the wastewater treatment facilities needed to achieve the goals of the Act.

"208" - Refers to Section 208 of the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500). Section 208 provides for the designation of areawide waste treatment management planning agencies for the purpose of "developing effective areawide waste treatment management plans" for areas that, because of "urban-industrial concentrations" or other factors, have "substantial water quality control problems." The areawide approach is aimed at integrating controls over municipal and industrial wastewater, storm sewer runoff, nonpoint source pollutants and land use.

APPENDIX B

Technical Description of the Land Use Allocation System

APPENDIX B - TECHNICAL DESCRIPTION OF THE LAND USE ALLOCATION SYSTEM

REQUIRED CHARACTERISTICS OF THE LAND USE INFORMATION SYSTEM

The selection of a land use information system for the study demanded careful attention because of its relationship to the analytical requirements of the air and water quality models. The land use information system had to satisfy three key elements:

1) capable of being used by the various air and water models,

2) capable of being used in the predictive methods used in allocating future land uses and

3) capable of being related to the existing county and city land use systems in Sonoma County such that the study findings could be transferable.

The most important of the three elements was its adaptability to air and water quality modeling requirements. From the air modeling perspective, the land use system had to provide for the model variables used in distributing area and mobile emission sources. Area sources were distributed according to the population in the residential land uses. (They could also have been distributed by employment in the industrial and commercial land uses.) Mobile emissions were determined as a function of the average daily traffic (ADT) on the road network. The ADT was projected using traditional but somewhat dated transportation modeling variables of "productions" and "attractions" of various land uses. Planning agencies wishing to conduct similar analysis should recognize that transportation modeling is continuously in a state of change and improvement. Recent transportation models have been developed that are more sensitive to such variables as structure of household, family size, accessibility functions (time and costs) and auto availability. Therefore, any new program aimed improving on the Sonoma Study should give particularly attention to reviewing new transportation models and should consider adapting their land use classification systems to the needs of those new models.

In relationship to surface runoff model needs, the principle importance of the land use information system is its adaptability to the impervious surface and pollutant loading descriptions. A key consideration is how precise the land use classification must be with respect to model requirements. Because information on pollutant loading is no more refined than such basic land use categories as residential, industrial or commercial (Water Pollution Aspects of Street Surface Contaminants, Sartor and Boyd, 1972), greater detail in the classification system is not warranted. Similarly, the information on impervious surface characteristics, because the model generalizes it for a wide geographic area, requires only a simple classification system. Furthermore, the surface runoff model does not require a system that provides for a high level of spatial resolution. The model adds all the land use categories within a hydrologic sub-area and computes for a total sub-area impervious surface factor or a total pollutant load for all land uses. Therefore, a land use classification system that provides for great resolution is not required.

The steps to be learned from the study in developing or adapting a land use classification system for air or water quality modeling are:

1) determine the governmental policies that are to be investigated

2) determine the capability of the various air and water models to assess the effectiveness of the policies and

3) determine the characteristics of the land use classification necessary as inputs to the models.

Future planning efforts should avoid selecting land use information systems that require great spatial resolution or highly detailed land use categories when they are not warranted for the water or air quality models unless, of course, the systems can and will be used for other planning purposes.

REVIEW OF ALTERNATIVE METHODS FOR ALLOCATING GROWTH

Several methods for allocating future residential, commercial and industrial growth were reviewed at the outset of the study. It was initially decided to use a computerized system for allocating future land uses because of the extremely large amount of information to be evaluated. The following land use projection and allocation techniques were examined:

1. PLUM (Projective Land Use Model)

   The PLUM model distributes future population and basic and local service employment into subregional zones and computes accompanying land use changes. It was developed by ABAG and the Metropolitan Transportation Commission (MTC) and has been used in the Bay Area Simulation Study, the Bay Area Transportation Study and as part of ABAG's ongoing regional projections program.

2. ZAP (Zonal Allocation Procedures)

   ZAP is a series of programs that allocate broad-area projections to smaller sub-units. Developed by Peat, Marwick and Mitchell, it is used in conjunction with EMPIRIC, an equivalent to PLUM. ZAP has been applied to several areas of country including Atlanta, Central Puget Sound, Washington, D.C. and Denver.

3. DYLAM/Lakewood

   DYLAM/Lakewood is designed to allocate land uses based on the "attributes" of each sub-regional measurement units and the relative desirability of this "attributes" to each land use. It projects land uses for each of approximately 1,000 40-acre grid cells. The City of Lakewood, Colorado in conjunction with Parsons, Brinckerhoff, Quade and Douglas, developed this model.

4. Modification of PLUM

   The modification of the PLUM model to include some of the same attractiveness factors as the DYLAM/Lakewood was also considered.

The attractiveness factors considered were: travel to employment centers, distance to major roads, presence of sewer system and other infrastructure, distance to service areas and presence of usual or recreational amenties.

All of the above methods for allocating growth were finally considered too complex or costly for the purposes of the study. Instead, future residential, commercial and industrial growth were allocated by locating the appropriate land areas needed for projected development according to the land use patterns established by the existing general plans of the cities in Sonoma County. The following sections of this appendix will describe the steps in that allocation process.

STEPS IN ALLOCATING FUTURE GROWTH

A seven step process was used for allocating future land use in Sonoma County. The end product of this process was distributed land uses, associated with projected population and employment, in a manner compatible with the air and water quality simulation models.

Step One - Determine Population and Employment Projections for the County

The Sonoma County Advanced Planning Department, as part of the General Plan preparation effort, had population and employment projections made per census tracts for two year 2000 population levels. These projections are contained in Baseline and Gronorth Projections, University Research Center, July, 1974.

The total county population figures of 478,000 and 630,000, both for the year 2000, were used in the study. The California State Department of Finance (DOF) projection figure of 478,000 people served as one level. This figure is derived from the DOF-100 series which is a population projection model (cohort survival) using a non-constant growth rate ranging from 4.0% to 1.7% between 1975 and 2000. The second population level of 630,000 is derived from ABAG's Regional Plan gronorth assumptions whereby there is a shift of population and employment towards the North Bay Area. The population growth rate varies between 4.3% and 2.6% between 1975 and 2000.

The number of residents in the labor force was next determined by multiplying a labor force participation rate by the different total population levels. An assumed number of unemployed are subtracted to obtain the number of employed residents. Adjustments were also made for both in-commuters and out-commuters. Finally, total employment was broken down according to different industrial categories including "basic employment" (e.g. agriculture, manufacturing, basic finance or insurance) and "non-basic" or "population-serving" (e.g. retail services, local finance, construction).

The output of this first step was total population and employment by industrial category that could be distributed to the various cities or unincorporated areas of the county in a manner consistent with the study's hypothetical development patterns.

Step Two - Select the Land Use Categories

Ten land use categories -- low density residential, medium density residential, high density residential, centered commercial, suburban commercial, industrial, grazing/open, orchard and vineyard agriculture, truck crop and field crop agriculture and wetlands -- were selected because they approximated the categories used by the various planning agencies in the county and they fit the needs of the simulation models.

Of particular importance to the selection of the land use categories was their similarity to the land use categories used in the basic surface runoff research on both pollutant loading rates and impervious surface coverage. For example, the two commercial categories -- centered and suburban -- were selected to permit a lower percentage impervious coverage for suburban shopping centers, which have an opportunity to cover less of their development areas than do their downtown counterparts.

One improvement that should be considered in future studies is a wider range of low density residential categories. The impervious surface characteristics can change as much as 50% between 10.8 dwelling units (d.u.) per hectare (5 d.u. per acre) and 6.5 d.u. per hectare (3 d.u. per acre). Similarly, the impervious surface coverage in older residential neighborhoods is about 10-15% lower than that for the new residential neighborhoods. Therefore, the land use categories should be carefully selected to reflect variables tested in the water quality models.

Step Three - Translate Population and Employment into Land Use

The third step was to transform the county population and employment totals into hectares of land use for the categories established in Step 2. An initial step in developing the amount of residential hectares was to divide a 2.5 persons per dwelling unit factor into the total population to get the number of future dwelling units in the county. The 2.5 factor was used in the study to maintain consistency with the county planning program. However, it would have been preferable to have varied a person per unit rate for each housing density to better approximate current or anticipated conditions.

A density average of 10.8 d.u. hectare (5. d.u. per acre) was assigned to the low density class because it approximates the gross density resulting from 6,000 square foot lots -- the present minimum single family lot size for much of the county. While the present average density of single family dwelling units in Sonoma County cities is probably lower than 10.8 d.u. per hectare, the trend is toward higher densities. A high percentage of new single family subdivision developments have been built at this higher density in recent years.

The medium density class was assigned a desnity of 32.6 d.u. per hectare (15 d.u. per acre) because it represented an average density for the multi-family dwelling units being constructed currently in the county. Structural types in this category represent a range from 2 story townhouses with a high floor area ratio to 2 and 3 story apartments with moderate to low floor area ratio.

The high density category was assigned a desnity of 69.5 d.u. per hectare (32 d.u. per acre) for the following reasons:

1) it was the highest density obtainable in three story apartment units.

2) it represented a flexible range in multi-family structural types - from three story walk-ups to four, five, and six story apratment buildings with respectively lower floor area ratios.

3) it was determined from initial calculations that a very high level density class would be necessary to accommodate the population growth in the cities without unreasonably expanding their boundaries or making the spacial patterns among the various development alternatives too similar.

The process of translating employment to land use required first the correlation of the various industrial employment categories to their comparable commercial and industrial land use classifications. This was achieved simply by allocating to the commercial land use category those "basic" or "local serving" employees most likely to be located in offices or stores. For example, employment in "basic" finance and insurance and "local serving" banking was assumed to be located in commercial land uses.

The amounts of land used by either the industrial or commercial land use categories were then derived by the use of an employee per hectare factor determined for each category. These factors were developed from:

1) the 1970 Federal Highway Administration report by Edward A. Ide, Estimating Land Use and Floor Area Implicit in Employment Projections, (Federal Highway Administration, July, 1970) Table 2.1, pp. II-13 to 11-17 and

2) the comparisions of Sonoma County's 1971 land use inventory to the 1970 Census of Employment.

The factors were adjusted according to the density configurations desired for a particular growth pattern tested in the study or to particular industrial activities for which the single factor was inappropriate. The commercial employee per hectare factors ranged from 314.8 employees per hectare (145 employees/acre) in suburban commercial locations. The industrial factors ranged from 43.4 employees per hectare (20 employees/acre) for more labor intensive industrial categories to 26.1 employees per hectare (12 employee/acre) for less intensive industries such as transportation or storage.

Step Four - Designate Land Unsuitable for Development

A number of geographical sections of the County within the study area were determined to be unsuitable for urban development. The criteria used for defining such areas were those areas with slopes greater than 30% and existing park land. Other criteria were considered including land within a flood plain and land outside a sewer district. These were dropped because the existing local policies do not uniformly preclude development in those areas.

Step Five - Determine Intent of Each Growth Alternative

The fifth step was to determine the land use allocation assumptions to be used in each growth alternative. The purpose of these assumptions was to provide a method by which the countywide land use category totals could be allocated to the cities in the study area. The desired growth patterns are described in Chapter V.

The assumptions included:

1) the relative size of the various cities to the total county population, e.g., 80% of the County's population will be urban; 50% of the total County population will live in Santa Rosa, 25% in Petaluma, etc.

2) the residential density configurations within each city, e.g., 10% will be high density, 40% medium and 50% low.

3) the location of residential development, e.g., all of the high density development will be located in general plan, high density category that is most centrally located.

4) the relative size of employment in the various cities to the total county employment, e.g., 70% of "basic" commercial will be located in Santa Rosa; 60% of "non-basic" commercial and industrial will be located in Santa Rosa.

5) the location and density of the different commercial and industrial categories, e.g., 100% of "basic" commercial at 314.8 employees per hectare will be located in the center of Santa Rosa; 50% of "local-serving" commercial at 130.3 employees per hectare will be located at the suburban or fringe commercial districts of Santa Rosa.

Step Six - Allocate Land Use to Each Grid Cell

Based on the allocation assumptions established in Step 5 and the required number of hectares for each land use category as established in Step 3, it was next possible to calculate the land use categories for each city and locate them according to the development pattern established by the various general plans. When the general plans were not consistent with the study allocation assumptions, the study assumptions predominated. Next the one kilometer grid pattern was laid over the allocated land uses and the percentage of each land use category per grid cell was determined.

Step Seven - Translate the Land Use Information Per Grid Cell to a Computer Format

The final step in the land use allocation process was to translate the percentage of each land use per grid cell into a computer format useable by both the air and water model. The computerized data from all the grid cells was tabulated for the study area to verify that it conformed with the initial county population and employment control totals.

APPENDIX C

Technical Description of the Modeling System for Non-reactive Air Pollutants

and

Meteorology and Air Quality in Sonoma County (Modeling Input and Calibration)

APPENDIX C

PART I - DESCRIPTION OF MODELING TECHNIQUES

MODELING PHILOSOPHY

The BAAPCD modeling techniques are designed to address a variety of considerations. First, they are designed to provide answers to the questions most frequently asked by local and regional planning agencies including air quality impacts of various projects that are being evaluated. Secondly, the modeling techniques consider the more general regional nature of the air pollution problem and the relationship of primary air quality standards to the pollutant concentrations throughout the various geographical sectors of the San Francisco Bay Area. On the basis of these considerations, the modeling approach was developed with the following characteristics:

1. It should consider the contributions from all sources, local as well as regional and background.

2. While regional in nature, it should have the capacity of resolving the impacts of local sources.

3. It should provide information on transport of pollutants from remote sources.

4. It should provide the basis for statistical estimates of the probability of exceeding air quality standards.

5. It should reflect an ambient impact in keeping with the mobility of the population and the resolution limitations of modeling techniqes.

To meet these requirements, a regional, climatological, gaussian dispersion model was developed and coupled with a statistical concentration frequency estimation model. The dispersion model was split into two separate sub-models: a regional, low resolution sub-model and a local high resolution sub-model. The complete model was designed to yield the following information on a resolution of one square kilometer:

1. The annual arithmetic mean concentration for each contaminant.

2. The number of times per year an air quality standard is violated.

3. The portion of the problem derived from local sources versus the portion imported from outside the immediate study area.

Use of a climatological model on an area averaged basis has the effect of smoothing or averaging out the large random error fluctuations inherent in short term, point by point modeling applications. Residual error in the climatological model (which can with care be reduced to 20% or less of the true climatological average) is amendable to further reduction through model calibration, if a long-term record of contaminant and meteorological data is available. The same data record may be used as the basis for a statistical recovery of spatial and temporal detail lost in the climatological smoothing process. The output is a modeled probability distribution of contaminant concentrations which is a function of local and regional climatology and any assumed geographical distribution of emissions. The form of the output is quite useful for planning and design applications.

MODEL DETAIL

The Dispersion Model

In modeling dispersion for a large, complex region such as the San Francisco Bay Area, it is useful to conduct simulations for different geographic scale. This can be done on the basis of various dispersion-transport scales and source categories, thus allowing for flexibility in the choice of modeling techniques for the individual modules and facilitating the separation of output concentrations into component contributions. In constructing the Bay Area Planning Model, two scales of dispersion-transport were considered: a "regional" scale with a coarse resolution on the order of several hundred square kilometers (county size) and a "local" scale with a much finer resolution on the order of one square kilometer. A different modeling approach was used on each scale.

Regional Scale Sub-Model. In the regional case, it is assumed that contaminants, after travel distances of tens of kilometers or more, are quite thoroughly mixed vertically and horizontally, and their concentrations appear as background to any strong local sources. On the regional scale, therefore, where a large percentage of the area is source-free open space, a box model with uniform volume mixing is a resasonable model for estimating average county scale concentrations. Regional transport conforms to a streamline pattern influenced by prominent terrain features. A climatological set of such patterns was developed for the San Francisco Bay Area by Clarence Smalley (1957) and is ideal for the climatological modeling of regional transport.

In constructing the regional scale sub-model, resoultion is limited to the individual counties comprising the BAAPCD because emissions inventory data are currently prepared annually for each county with no finer resolution available. A "box" is defined for each county by extending a vertical plane, originating at the county political boundary, between the sea level surface and the climatological average of inversion base height as determied from Radiosonde ascents at Oakland International Airport. The effect of hills or mountains is accounted for by reducing the source area volume in each box by the amount that is displaced by the irregular terrain. The dilution

effect of wind flow through each box is accounted for in terms of residence time computed as the dimension along the principal streamline through the county, divided by the mean annual county wind speed. Resultant values of adjusted source area (A_e), inversion base height (H) and residence time (R) are given in Table C-1.

Transport from county to county through complex terrain is handled in terms of Smalley patterns mentioned above (Figure C-1 and Table C-3). From each of the patterns, a subjective estimation is made for each county box of the relative contribution of upwind boxes to the imported background concentration. These relative contributions for each Smalley pattern are then multiplied by the annual recurrence frequencies of the patterns to obtain a set of annual average contribution weighting factors as given in Table C-2.

Table C-1

COUNTY BOX MODEL PARAMETERS

	A_e (meters^2 x 10^9)	H (meters)	R (days)
ALAMEDA	1.71	457	0.25
CONTRA COSTA	0.95	457	0.18
MARIN	0.90	457	0.20
SAN FRANCISCO	0.22	457	0.04
SAN MATEO	1.03	457	0.12
SANTA CLARA	1.31	457	0.33
NAPA	1.04	457	0.14
SONOMA	1.28	457	0.35
SOLANO	0.94	457	0.14
DISTRICT	9.38	457	0.50

In applying the regional model, a computation of contaminant concentration is first made for each county box using the formula:

$$C = \frac{ER}{A_e H} \qquad (1)$$

Where
C = annual averaged box concentration
E = annual box emission rate
R = annual averaged residence time
A_e = adjusted source area
H = annual averaged inversion base height

Table C-2

COUNTY WEIGHTS FOR TERRAIN ADJUSTED BOX MODEL ADVECTION

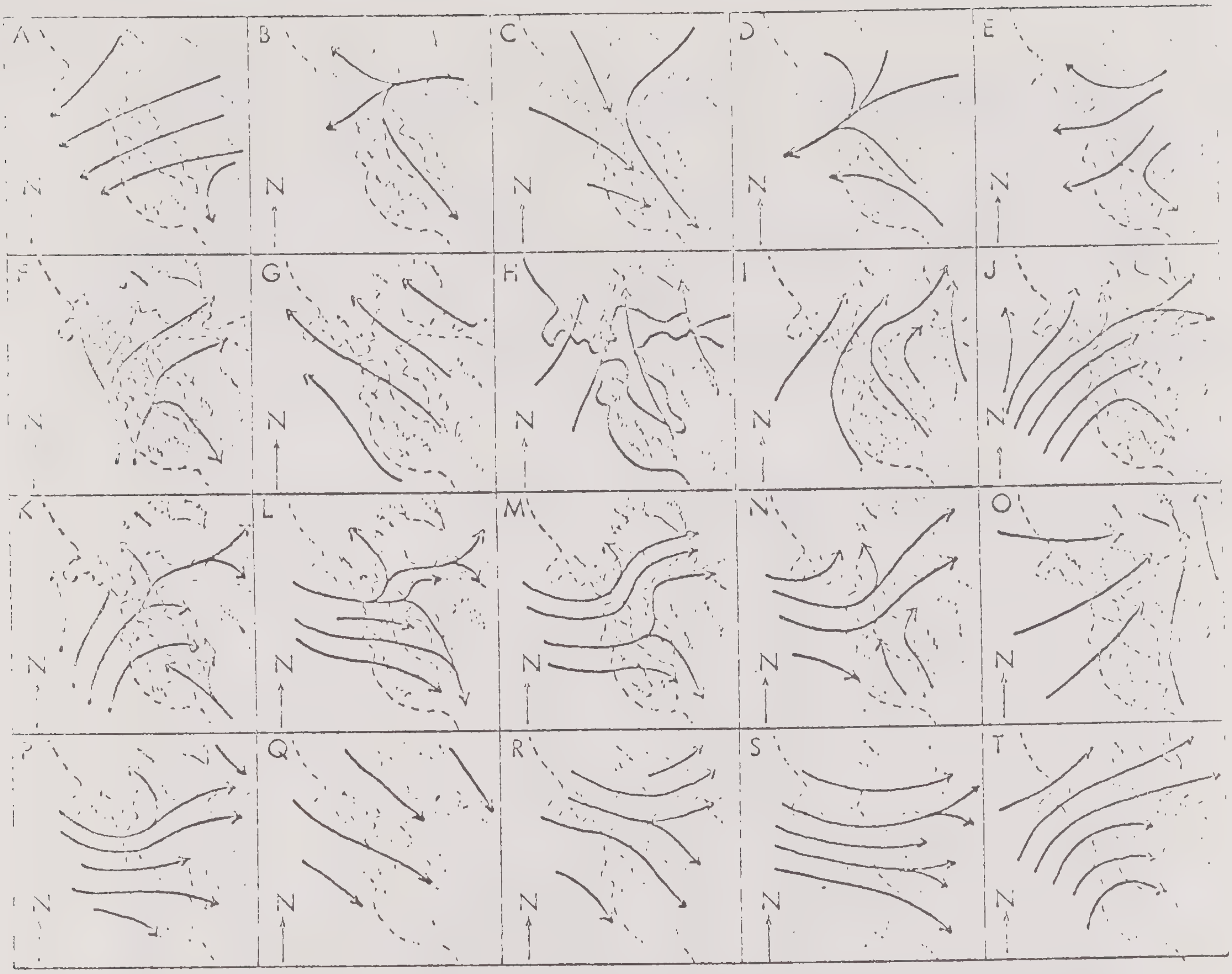
	Alameda	Contra Costa	Marin	San Fran.	San Mateo	Santa Clara	Napa	Son-oma	Solano
Alameda	1.00	0.08	0.06	0.32	0.19	0.15	0.01	0.01	0.01
Contra Costa	0.09	1.00	0.24	0.24	0.03	0.05	0.04	0.04	0.08
San Francisco	0.00	0.04	0.03	1.00	0.09	0.09	0.00	0.01	0.05
San Mateo	0.03	0.04	0.02	0.11	1.00	0.12	0.00	0.00	0.00
Santa Clara	0.40	0.02	0.02	0.20	0.37	1.00	0.01	0.01	0.02
Napa	0.05	0.13	0.46	0.20	0	0.04	1.00	0.36	0.07
Sonoma	0.02	0.02	0.36	0.04	0.03	0.02	0.02	1.00	0.02
Solano	0.07	0.16	0.35	0.10	0.02	0.06	0.35	0.34	1.00

Total concentration for a county is obtained by multiplying County Box Model concentrations by the weighting factors in the table and summing across a receptor row.

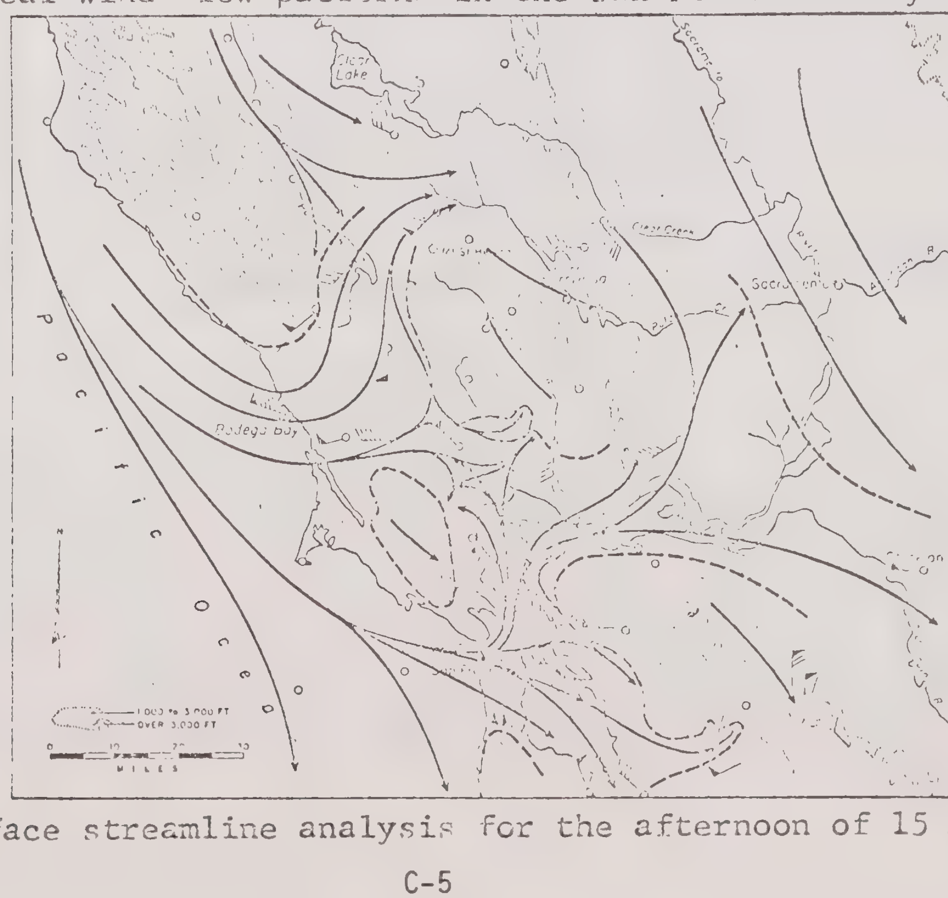
Weighting factors were obtained by analysis of Smalley Flow Patterns to arrive at an estimate of advective contribution from out of County sources.

Weighting factors represent the fraction of the time that a receptor in a county at the left would receive a pollutant contribution from sources in a county at the top.

Figure C-1



a. Typical wind flow patterns in the San Francisco Bay Area



b. Surface streamline analysis for the afternoon of 15 August 1962

Table C-3

Percent monthly occurrence of typical wind flow patterns (1952-1955)

Pattern type	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Yearly Avg.
	Month												
A	1.2	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	1.2	3.2	0.7
B	6.4	5.6	1.6	1.0	0.2	0.0	0.0	0.2	0.2	1.2	2.9	7.2	2.3
C	3.6	9.0	8.1	2.3	1.8	0.6	0.0	0.0	0.4	4.8	3.7	3.4	3.1
D	8.1	3.4	0.8	0.2	0.0	0.8	0.0	0.0	0.2	0.2	2.8	8.6	2.2
E	2.4	3.1	2.9	0.2	0.2	0.0	0.0	0.0	0.0	0.4	0.7	4.0	1.1
F	0.2	0.5	0.6	1.3	0.6	2.5	0.2	1.2	1.2	2.0	0.2	0.2	0.9
G	13.2	4.3	7.0	2.7	0.0	0.0	0.0	0.6	0.2	0.2	8.1	17.6	4.6
H	5.9	3.6	2.6	2.7	0.8	1.0	0.0	0.4	0.6	1.0	1.5	5.0	2.1
I	5.3	1.6	2.2	3.1	1.0	1.0	0.0	0.8	1.7	3.0	2.1	1.8	2.0
J	0.4	0.5	0.8	2.1	1.8	3.3	3.6	2.1	6.2	2.9	0.2	0.0	2.0
K	0.1	0.2	1.6	1.9	0.2	0.6	1.0	1.0	0.6	1.2	0.0	0.0	0.7
L	0.6	1.8	1.6	5.4	6.3	5.4	19.7	17.6	9.8	4.9	1.0	0.4	6.2
M	0.2	0.7	4.0	6.0	7.9	13.3	14.9	16.0	10.4	8.9	1.6	0.8	7.0
N	3.5	2.1	7.1	5.0	9.7	7.8	5.8	9.0	6.2	3.4	2.9	2.2	5.6
O	7.3	5.5	7.4	7.4	5.0	5.7	2.2	4.9	3.5	2.4	2.4	3.2	4.2
P	1.0	2.7	3.8	5.0	7.5	9.2	4.8	3.7	7.5	7.5	1.4	0.2	4.5
Q	3.4	8.3	7.2	8.6	11.9	3.8	1.4	1.7	2.9	7.7	7.6	8.1	6.0
R	1.8	5.0	8.9	11.3	12.3	11.3	13.5	15.3	9.6	7.5	1.5	2.2	8.3
S	1.2	3.6	9.7	12.7	14.7	24.2	23.1	18.3	14.1	4.3	1.9	2.4	10.7
T	0.2	0.9	1.0	2.7	1.6	1.0	1.4	1.7	0.0	2.0	0.9	0.4	1.1
[a]LV & UC	33.7	36.1	20.9	18.5	16.5	8.4	8.5	5.4	22.9	33.9	55.3	28.9	24.6

[a]LV = light and variable
UC = unclassified

The resulting concentration may be construed as a "county background" concentration due solely to sources within the county and does not apply to locations within a kilometer or so of any strong local source. By applying the weighting factors of Table C-2 to the individual county box concentrations obtained through equation (1), contributions from other counties may be added to produce an estimate of background from all San Francisco Bay Area sources on a county by county basis. While such estimates are crude, they are quite useful in indicating the relative impact of various sections of the Bay Area upon local concentrations. Source categorization is relatively unimportant on the regional scale because surface, elevated, point, line and area sources are all quite thoroughly mixed over the long average travel distances involved.

Local Scale Sub-Model. On the local scale, modeling detail becomes much more important and the choice of modeling technique depends upon the source category being modeled. For the most part, urbanized locales consist of clusters of small stationary sources and networks of line sources (streets and highways). In those locales where heavy industry is located, the large stationary sources should be considered as a separate category. In approaching the local area source problem, the two mechanisms of dispersion and transport again come into play. If emissions are assumed horizontally uniform within a local source area, dispersion will take place almost exclusively in the vertical. The extent to which locally produced pollutants are dispersed will be determined by the wind speed, the balance between turbulent transport and emission rates and the duration of the dispersal mechanism or travel time within the local source area. Under a undirectional wind regime, downwind concentrations will be higher than upwind concentrations as the result of superposition. On an annual averaged basis, several directions are involved and concentrations would be expected to be distributed with much less directional bias. The local area source problem is similar to the regional box model problem with one additional level of sophistication: in the regional case, pollutants are assumed to be distributed uniformly both horizontally and vertically. In the local case, horizontal uniformity is still assumed within the source area, but because of the smaller average distance between source and receptor points within the source area, complete mixing in the vertical cannot be assumed as an average condition. A concentration profile must therefore be assumed in the vertical.

Two basic methods are traditionally employed in modeling the vertical (and horizontal) distributions of contaminants. One is to solve the diffusion equations employing diffusivity coefficients related to terrain and meteorology on the basis of boundary layer similarity theory. The other is to assume the steady state gaussian plume model with normal plume concentration deviation parameters derived empirically and related to meteorological factors alone. Both of these approaches work best when applied on an infinite plane, with uniform meteorological conditions and a uniform terrain. When applied to urban areas, particularly in complex terrain, both of these methods require the judicious use of adjustment parameters. The gaussian method has the principal advantage of requiring less extensive computational requirements that

lend themselves readily to simplification. The steady state assumption, characteristic of gaussian modeling, while considered a drawback in episode modeling, is quite appropriate in climatological modeling of the type required for the study. After considering the various alternatives it was decided to employ the gaussian method in developing the local scale sub-model.

The local scale sub-model is run on a computational grid with a one-kilometer mesh size. The grid size is variable but is no larger than an area that can reasonably be assumed to be represented meteorologically, on an annual averaged basis, by observations at a single site. Choice of grid location is such that terrain features will not unduly interact with transport throughout the grid. Since most of the densely developed areas throughout the Bay Area are areas of locally level terrain, and are characterized locally by relatively uniform low profile construction and vegetation, the local sub-model is applicable to a large percentage of the urbanized Bay Area. In hilly or mountainous areas, areas with rapid horizontal gradients of meteorological parameters, or areas with large non-uniform structure profiles, such as downtown San Francisco, the usefulness of the model is doubtful, and special methods must be employed. The Sonoma study area, fortunately, has reasonably level terrain.

Computation on the local grid proceeds in two distinct steps. First of all, the average annual concentration is obtained for each individual 1-kilometer grid square considering only those sources located within that grid square. In doing this, emissions from all sources within the grid square are totalled, and an area source strength is computed in units of mass per unit area per unit time. Average contaminant concentration in the grid square is then computed by the formula

$$\overline{C} = \left(\frac{2}{\pi L^2 U^2}\right)^{1/2} \int_{\Theta}^{L} \int_{\Theta}^{X'} \frac{Q_a}{\sigma_z(X)}\, dX dX' \qquad (2)$$

where $\overline{C}$ is the average grid square concentration
Q_a is the grid square source strength per unit area
L is the grid mesh size (1 kilometer)
U is the wind speed

and $\sigma_z(X)$ is the plume standard deviation as a function of downwind distance, X. The quantity (Θ) is an offset distance used to account for initial mixing at volume sources. Formula (2) is simply the double integration of the gaussian line source model over the length of a grid square, once to obtain the concentration as a function of downwind distance, X', and once to average all downwind concentrations over the grid square. The quantity $\sigma_z(X)$ over a 1 kilometer distance is closely approximated in the form:

$$\sigma_z(X) = aX^b \qquad (3)$$

where a and b are constants whose values have been determined empirically for various meteorological conditions. In the Bay Area model, the annual average dispersion is computed by using a weighted average value of σ_z in the form:

$$\sigma_z = 0.75\ \sigma_d + 0.25\ \sigma_n \qquad (4)$$

where σ_d = 0.133 x 0.91 (daytime-evening)
and σ_n 0.094 x 0.79 (early morning)

The second step in the grid computation involves the interaction between grid squares as pollutants are transported by the wind. As a pollutant cloud leaves a grid square and continues on its way, dispersion continues vertically, but horizontal dispersion takes on greater importance as travel distance increases due to erosion at the edges of the initially (assumed) uniform cloud. When considering the contribution from an upwind grid square, on an annual average basis, the horizontal and veritical dispersion as well as the directional frequency of wind must be taken into account. This was done in the Bay Area Model by considering upwind grid squares as point sources located at the grid square centers. Emissions are then assumed to diffuse downwind as a plume with gaussian distribution in the vertical, and a uniform distribution crosswind within the angular confines of a single wind rose sector. With this rationale, the annual average contribution to the concentration in any downwind grid square, i, from sources in any upwind grid square, j, may be computed as:

$$C_{i_j} = \frac{2Q_j N}{(2\pi)^{3/2}\ \sigma_z\ UX} \qquad (5)$$

where
Q is the point source strength in terms of mass per unit time, N is the number of wind rose sectors and X is the distance between centers of the source and receptor grid squares. The total contribution, on the annual average, from all upwind elements is obtained for each receptor grid square by summing over all upwind elements and all wind rose secdtors, weighting each sector by the annual frequency of occurrence of its direction. Finally, the concentration components in each grid square, from its own sources and from upwind sources, are combined with the regional scale background and any assumed global or natural background to yield the total local scale annual average concentration. To avoid duplication, the county scale background is computed after subtracting emissions associated with the local scale grid. Because of the modular approach used in the model, it is easy to output the individual component concentrations so that the relative contributions of various segments of the local and regional source area may be assessed.

The Statistical Model

This section discusses the application of a statistical model developed by Dr. Ralph Larsen (1971) of EPA. The research by Larsen has established

the lognormal distribution as a workable assumption for the distribution of contaminant concentration data. Larsen has further demonstrated that the dependence of the lognormal statistics on averaging time is described in a simple analytic form. These results enable, through a simple, semi-empirical technique, the combining of output from the climatological model with statistics derived from our air monitoring network to produce the necessary statistical information most useful in land use planning applications.

Model Characteristics

In a lognormal distribution as assumed by Larsen, the logarithms of observed pollutant concentrations have a normal or gaussian distribution. We may therefore define a standardized variable or "Z-score" in the form

$$z = \frac{\ln X - m}{s} \qquad (6)$$

where
X is the observed pollutant concentration and m and s are the mean and standard deviation, respectively, of the concentration logarithms. Expression (6) may then be solved for X in the form

$$X = (e^m) \cdot (e^s)^z \qquad (7)$$

where e^m is the geometric mean (MG) and e^s is the standard geometric deviation (SGD) of the concentration distribution. Equation (7) is an important one for our application since pollutant concentrations and their probabilities of occurrence (a known function of Z) are related if MG and SGD are known. The latter two parameters are functions of the averaging times of the pollutant concentrations. If their values are known for any averaging time, a, the corresponding values for any other averaging time, b, are given according to Larsen's model in terms of the relationships

$$(MG)_b = (MG)_a \text{ EXP } [0.5(1-v)\ln^2 (SGD)_a] \qquad (8)$$

and

$$(SGD)_b = (SGD)_a^{\sqrt{V}} \qquad (9)$$

where $$V = \frac{\ln (T/b)}{\ln (T/a)} \qquad (10)$$

T being the total averaging time of the data set, usually, 1 year. The arithmetic mean (MA) may be used in place of MG because the two are related in accordance with the formula

$$MA = MG \cdot \text{EXP } (0.5 \ln^2 SGD) \qquad (11)$$

The arithmetic mean is invariant with averaging time.

In applying the statistical model, the distribution of contaminant concentrations as represented by equation (7) is assumed to represent the influence of several component processes. We have found it reasonable to consider these components in two categories: those that contribute primarily to the pollutant concentration mean and those that contribute to the concentration variance. The former are assumed related primarily to the extent of human activities development (sources) while the latter are assumed related primarily to climatology.

With this rationale, the output of the dispersion model, previously described, is treated as the arithmetic mean of the pollutant concentration distribution. The standard geometric deviation is considered as a climatological parameter, and is obtained by analysis of past pollutant concentration data. If long enough records of data are available, estimates of meteorologically based year to year variability may be obtained for both the mean and the variance. When the mean and variance have been obtained, preferably with an estimate of their variability, equations (7) through (10) may then be used to obtain the recurrence frequency of any desired pollutant concentration value.

The principal asset of the statistical model just described is its role in minimizing the necessary sophistication of the dispersion model without sacrificing the necessary detail of the concentration variability. Normally, the concentrations resulting from extreme meteorological conditions such as calm winds, recirculations, fumigations, etc. cannot be handled very accurately by currently available dispersion modeling techniques. Moreover, any model that would be considered even reasonably suited to this task would be extremely sophisticated. Thus, episode modeling, in which concentrations are related to emissions under specific sets of meteorological conditions, has not met with a great deal of success in the extreme situations that are of greatest interest from an air quality standpoint. When modeling is done on a long-term averaged basis, over a season or a year, however, as is the case in climatological modeling, fairly simple models produce results of very useful accuracy. Moreover, because the effects of nearly all possible meteorological regimes are contained statistically in the variance of any historical data record, the variability lost through the long-term averaging may be recovered for statistical applications. Finally, if the variance in the data is climatologically based, as has been assumed in this study, a prognostic capability particularly suited to the needs of land use planning is achieved.

OPERATIONAL CONSIDERATIONS

Input Requirements

In order to operate the model, certain types of data in specified format are required as input information. These fall into four basic categories as follows:

1) Regional scale emissions data: On the regional scale, the model is currently configured to operate with county resolution. On this scale there is a requirement for the total annual average emission in tons per day for each county and for each contaminant of concern. Subroutines for terrain adjustment and calculation of Smalley pattern advection are included in the model code.

2) Local scale emissions data: On the local scale, the model is configured to operate with a resolution of one square kilometer on a grid of one kilometer by one kilometer squares. On this scale there is a requirement in each grid square for the total daily average vehicle-mileage, mean route speed and the total population. Emissions corresponding to this information is calculated using currently accepted emission factors.

3) Statistical data: To implement the statistical portion of the model, estimates of the SGD for the local area and pollutants of concern, and estimates of the climatological variability of both mean and SGD must be supplied. The BAAPCD is engaged in an ongoing program of research to provide this information on a comprehensive and up-to-date basis.

4) Point source data: As mentioned earlier, emissions from large stationary sources are not included among the emissions treated by the model, but are considered separately. This usually involves using standard gaussian plume dispersion techniques, and superimposing the resultant ground level concentrations on thos obtained from the regional model. In order that the effects of large stationary sources may be properly included in the modeling effort, detailed information is provided on the rate of emissions in units of mass per unit time, along with data on flue gas exit temperature and velocity, internal flue geometry and the geographic location and height above ground of each emission point.

LOCAL CLIMATOLOGICAL FEATURES

The Sonoma County study area, as indicated in Figures II-1 and II-2, lies in the northern portion of the nine-county San Francisco Bay Area in a region of complex terrain features. The climate consists generally of a warm dry summer season and a cool wet winter season comprising a climatic type frequently referred to as "Mediterranean." Juxtaposition of the study area to the nearby Pacific ocean coupled with the presence on the west of a relatively low terrain profile provide for a predominantly maritime influence, particularly in the western portions, although pronounced continental conditions occur with some frequency, particularly in the eastern portions. Four sub-regions comprising the study area are the Santa Rosa plain, which experiences the greatest maritime influence, the Petaluma Valley to the south and the Sonoma Valley (Valley of the Moon) to the east. The latter two valleys experience a climate more typically continental.

Summer maxima average from 29.4^{o}C (85^{o}F) on the Santa Rosa plain to near 32^{o}C (89.6F) in the valleys. Average summer minima are near 10^{oC} (35^{o}F). Sunshine is plentiful throughout the study are and precipitation averages near 76cm (30 inches) per year.

Conditions of wind flow in the study area tend to exhibit a complexity commensurate with the complexity of Bay Area and study area terrain features. The location of the study area in the context of regional Bay Area wind flow patterns is illustrated in Figure C-1. Statistics accompanying this figure are given in Table C-3. From the regional wind patterns it is evident that the study area is rarely subject to pollutant transport from the principal regional source areas south of the Golden Gate-Carquinez Straits axis. Terrain channeling of the local wind flow regime, as illustrated in Figure C-1, suggests a division of the study area into three sub-areas consisting of the Santa Rosa-Healdsburg area, the Rohnert Park-Petaluma area and the Sonoma Valley area.

Wind speeds in the study area tend to be quite light with typical annual averages ranging from 2.5 meters per second in the north to 3.5 meters per second in the extreme south. Larger urban areas experience lower than average wind speeds with typical values on the order of 1.75-2.0 meters per second as an annual average. The low annual averages are associated with a high frequency of near calm wind events.

Meteorological Modeling Input

Meteorology enters the model on two scales, regional and local. On the regional scale, transport to the study area from sources outside of the study grid is treated by the model in terms of the occurrence

statistics of regional wind patterns. Table C-2 provides the relative weighting on an annual basis of the frequency of association of source and receptor areas on a county scale. The weighting factors in Table C-2 are used, as described in Part I, to determine the annual average concentration due to regional non-grid sources. Annual average wind speed is also included as part of the regional sub-model for each of the counties in terms of a residence time for wind travel across the county dimension.

On the local scale, consideration is given by the model to the annual frequency of association of source and receptor grid squares in terms of a directional wind rose and an annual average transport wind speed. Wind rose and wind speed data available for use in the study area are presented in Table C-4. Roses 2, 8, and 10, from Table C-4, were chosen as representative of the Santa Rosa-Healdsburg, Rohnert Park-Petaluma and Sonoma Valley sub-areas respectively. An "intersquare transport" wind speed of 3 meters per second was chosen as typical of the study area with a small upward adjustment for increase of wind speed with height above the ground to reflect averaging of transport speed through a layer in the vertical.

Finally, modeling of source and receptor relationships within the same grid square requires an annual average wind speed for each individual grid square. Grid square wind speeds chosen for the study were of three types: an open area type chosen as 2.5 meters per second (slightly lower than the intersquare speed), a large urban center type chosen as 1.75 meters per second to reflect lowered resultant wind speeds due to urban roughness and finally a small urban center type chosen as 2 meters per second to reflect a roughness effect intermediate between the open areas and the large urban centers. The distribution of annual averaged grid square by grid square speeds as used in the model is given in Figures C-2 through C-4.

Current Air Quality in Sonoma County

Air quality in Sonoma County has been monitored somewhat sporadically since May of 1969 by the California Air Resources Board and the Bay Area Air Pollution Control District. A synopisis of monitoring intervals, locations and contaminants monitored is presented in Table C-5 and statistics of "full year" monitoring data are presented in Table C-6.

On the basis of these statistics, a set of factors were chosen for base year (1973) model calibration. Appropriate values for the standard geometric deviation (SGD) characteristic of the study area were chosen on the basis of Table C-6 and a set of area-wide patterns of SGD derived from monitoring data (Figure C-5). Hydrocarbon analysis presented a special problem. Monitoring data for base year were of total hydrocarbons (THC) obtained by propane spanned flame ionization instrumentation while the applicable air quality standard is for non-methane hydrocarbons obtained by methane spanned instrumentation. Reconcilia-

tion of modeling results and monitoring data for hydrocarbons was obtained on the basis of the curve in Figure C-7 based on comparison studies done in San Francisco.

Table C-7 is a presentation of the final set of statistics and calibration factors chosen for the study area. The values in the table were chosen to bring the modeling into reasonably close agreement with the observed situation in base year. It should be born in mind, however, that because the modeling is climatologically and spatially averaged and the monitoring data are not, exact agreement is unreasonable to expect. In future years, the modeling should be looked upon as comparative with alternatives compared under a standard set of atmospheric conditions.

Table C-4

Available wind data in the Sonoma County study area

Wind observation stations and maintaining agencies	Approximate coordinates (UTM)		Annual decimal frequency of wind direction by compass point																	Annual avg. wind speed (m/sec)
			Calm	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	
Santa Rosa Army Air Field (NWS)	4267	521	.203	.060	.016	.024	.003	.016	.017	.133	.083	.142	.041	.079	.021	.044	.012	.078	.028	2.5
Sonoma County Airport (FAA)	4263	516	.379	.049	.012	.014	.002	.008	.010	.099	.073	.117	.035	.058	.018	.032	.009	.061	.024	3.3
Jenner (NWS)	4258	490	.011	.010	.028	.038	.125	.088	.113	.034	.060	.042	.063	.057	.114	.070	.086	.041	.020	4.6
Santa Rosa (NWS)	4252	522	.044	.079	.004	.025	.003	.059	.004	.077	.014	.300	.020	.176	.010	.109	.009	.063	.004	2.5
Santa Rosa (BAAPCD)	4255	525	.023	.023		.054		.079		.094		.152		.291		.125		.092		1.75
Santa Rosa (CALTRANS)	4254	527	.001	.016	.027	.038	.042	.054	.033	.022	.034	.142	.195	.152	.088	.080	.044	.020	.012	2.7
Sonoma (CALTRANS)	4234	546	.003	.050	.013	.008	.009	.039	.052	.064	.048	.053	.021	.076	.250	.224	.026	.023	.041	3.8
Petaluma (CALTRANS)	4232	533	.002	.024	.009	.004	.010	.038	.068	.067	.023	.019	.020	.022	.064	.271	.151	.134	.074	3.1
Sears Point (CALTRANS)	4221	547	.001	.016	.009	.009	.012	.040	.033	.023	.031	.214	.047	.022	.030	.117	.156	.191	.049	3.9
Napa (BAAPCD)	4241	562	.014	.160		.038		.049		.153		.304		.138		.077		.067		2.0

NWS - National Weather Service
FAA - Federal Aviation Agency
CALTRANS - California Department of Transportation
BAAPCD - Bay Area Air Pollution Control District

Figure C-2

Printout of BASIC datafile in array format indicating annual average wind speed (m/sec) by grid square in modeling sub-section A (Santa Rosa). Areas of reduced wind speed are outlined and UTM coordinates of the sub-section boundaries are indicated as a reference

DATAFILE SPEEDSA IN UNITS OF METERS PER SECOND

508 531

4280 4280

2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	1.75	1.75	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	1.75	1.75	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	1.75	1.75	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	1.75	1.75	1.75	1.75	1.75	1.75	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	1.75	1.75	1.75	1.75	1.75	1.75	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	1.75	1.75	1.75	1.75	1.75	1.75	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	1.75	1.75	1.75	1.75	1.75	1.75	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.00	2.00	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50

4250 4250

508 531

Figure C-3

Printout of BASIC datafile in array format indicating annual average wind speed (m/sec) by grid square in modeling sub-section B (Rohnert Park-Cotati). Areas of reduced wind speed are outlined and UTM coordinates of the sub-section boundaries are indicated as a reference.

DATAFILE SPEEDSB IN UNITS OF METERS PER SECOND

508 531

4251 4251

2.50	2.50	2.50	2.50	2.50	2.50	2.00	2.00	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.00	2.00	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.00	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	1.75
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	1.75
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	1.75
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50

4221 4221

508 531

Figure C-4

Printout of BASIC datafile in array format indicating annual average wind speed (m/sec) by grid square in modeling sub-section C (Sonoma). Areas of reduced wind speed are outlined and UTM coordinates of the sub-section boundaries are indicated as a reference.

DATAFILE SPEEDSC IN UNITS OF METERS PER SECOND

530 4259 — 553 4259

1.75	1.75	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
1.75	1.75	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
1.75	1.75	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.00	2.00	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.00	2.00	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.00	2.00	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.00	2.00	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	1.75	1.75	1.75	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	1.75	1.75	1.75	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	1.75	1.75	1.75	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	1.75	1.75	1.75	1.75	1.75	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	1.75	1.75	1.75	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	1.75	1.75	1.75	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	1.75	1.75	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
1.75	1.75	1.75	1.75	1.75	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
1.75	1.75	1.75	1.75	1.75	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
1.75	1.75	1.75	1.75	1.75	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50

4229 530 — 4229 553

Table C-5

A HISTORY OF AIR MONITORING ACTIVITY IN SONOMA COUNTY

Year	Monitoring site	Interval	Agency
1969	Santa Rosa (1)	May - Dec	ARB
1970	Santa Rosa (1)	Jan - Dec	ARB
1971	Santa Rosa (1)	Jan - Apr	ARB
	Petaluma (1)	May - Dec	ARB
1972	Santa Rosa (2)	Aug - Dec	BAAPCD
	Petaluma (1)	Jan - Jul	ARB
	Petaluma (2)	Jul - Dec	BAAPCD
1973	Santa Rosa (2)	Jan - Dec	BAAPCD
	Petaluma (2)	Jan - Dec	BAAPCD
1974	Santa Rosa (2)	Jan - Dec	BAAPCD
	Petaluma (2)	Jan - Dec	BAAPCD

Santa Rosa (1)	37 Old Court House Square
Santa Rosa (2)	437 Humboldt Street
Petaluma (1)	12 North Petaluma Boulevard
Petaluma (2)	301 Payran Street

Table C-6

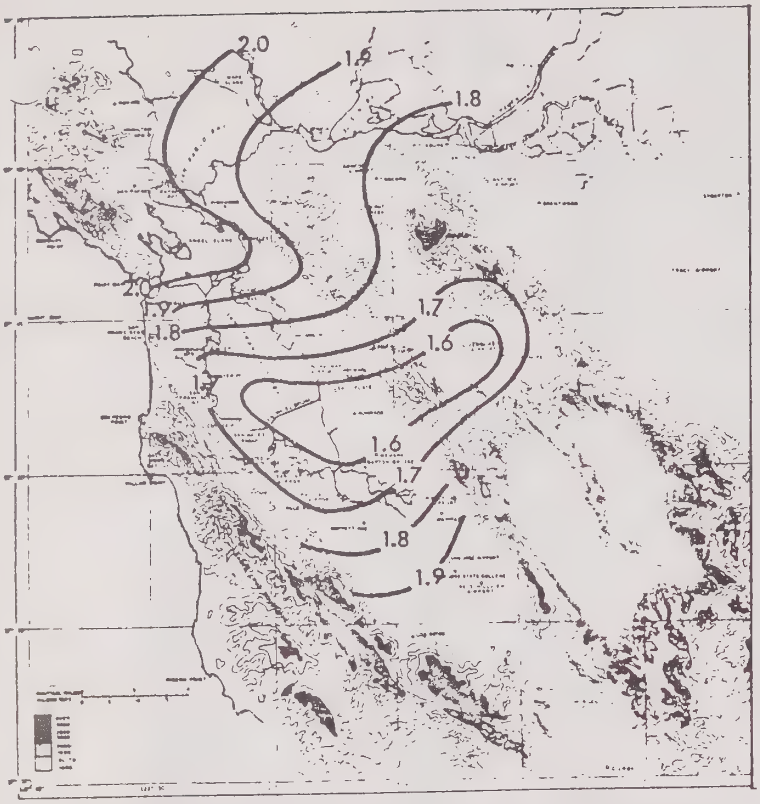
Available data on annual averages (M_a) and standard geometric deviations (SGD) for various pollutants in Sonoma County

Year	Monitoring Site	Carbon Monoxide (ppm)		Total Hydrocarbons (ppm)		Suspended Particulate ($\mu g/m^3$)		Oxidant (pphm)	
		M_a	SGD	M_a	SGD	M_a	SGD	M_a	SGD
1970	Santa Rosa	1.9	1.8	2.5	2.5	-	-	1.9	2.0
	(Petaluma)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
1971**	Santa Rosa	-	-	-	-	-	-	-	-
	(Petaluma)	(1.8)	(1.9)	(3.0)	(1.6)	(67^+)	(-)	(1.6)	(1.7)
1972	Santa Rosa	-	-	-	-	-	-	-	-
	(Petaluma)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
1973	Santa Rosa	*	*	2.2	1.3	40^+	-	2.1	1.6
	(Petaluma)	(-)	(-)	(-)	(-)	(-)	(-)	(2.2)	(1.6)
1974	Santa Rosa	*	*	2.1	1.8	43^+	-	2.1	1.5
	(Petaluma)	(-)	(-)	(-)	(-)	(-)	(-)	(2.2)	(1.5)

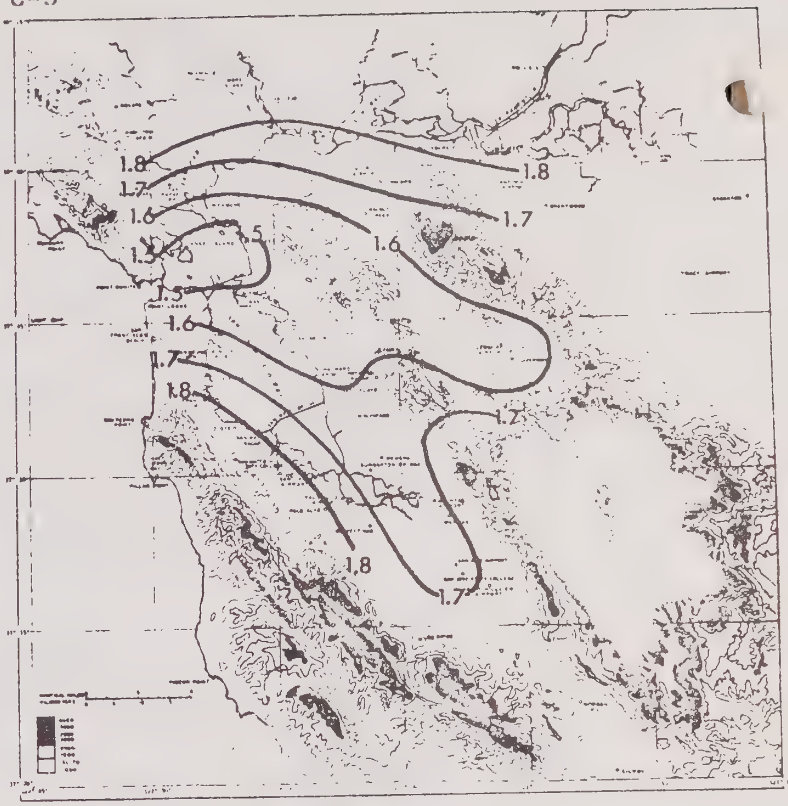
** May 1971 - April 1972
* Bad data
\- Partial data or no data
\+ Annual geometric mean

Note: Standard geometric deviation (SGD) is computed using only the 70th and 99th percentile values of the observed data with the assumption of a lognormal distribution.

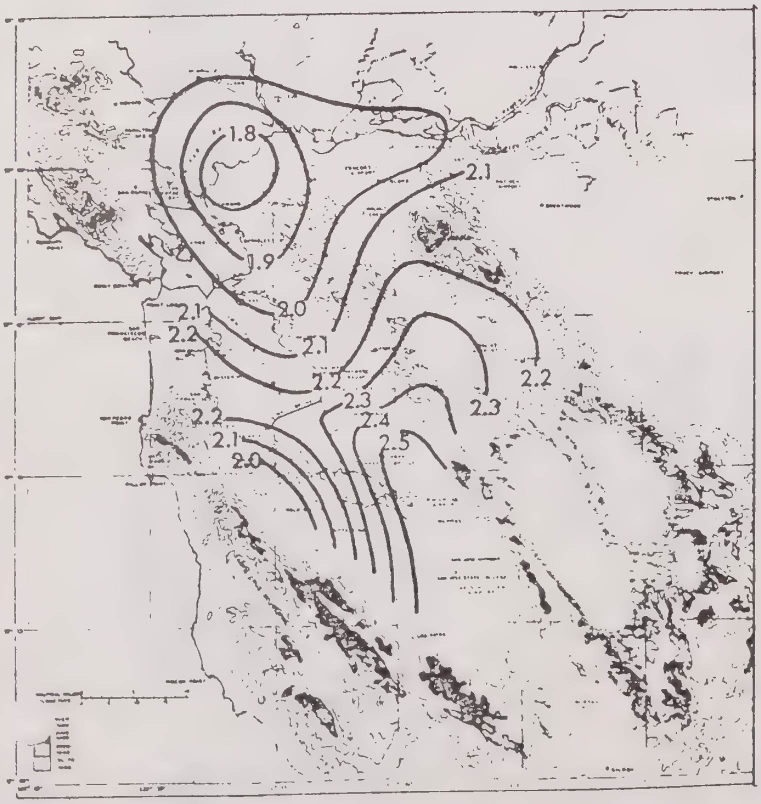
Figure C-5



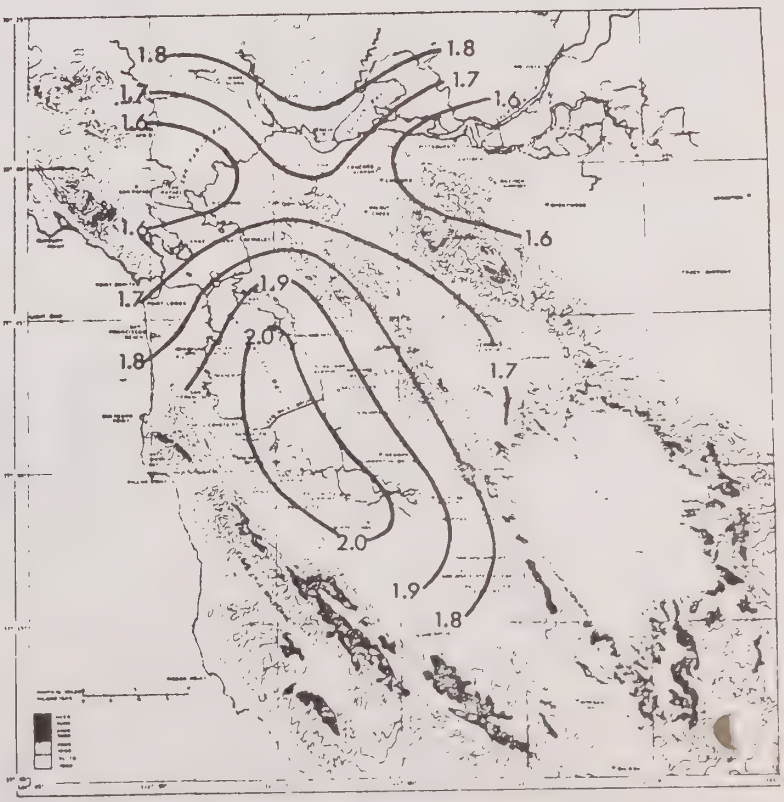
CARBON MONOXIDE AND HYDROCARBONS



SUSPENDED PARTICULATE



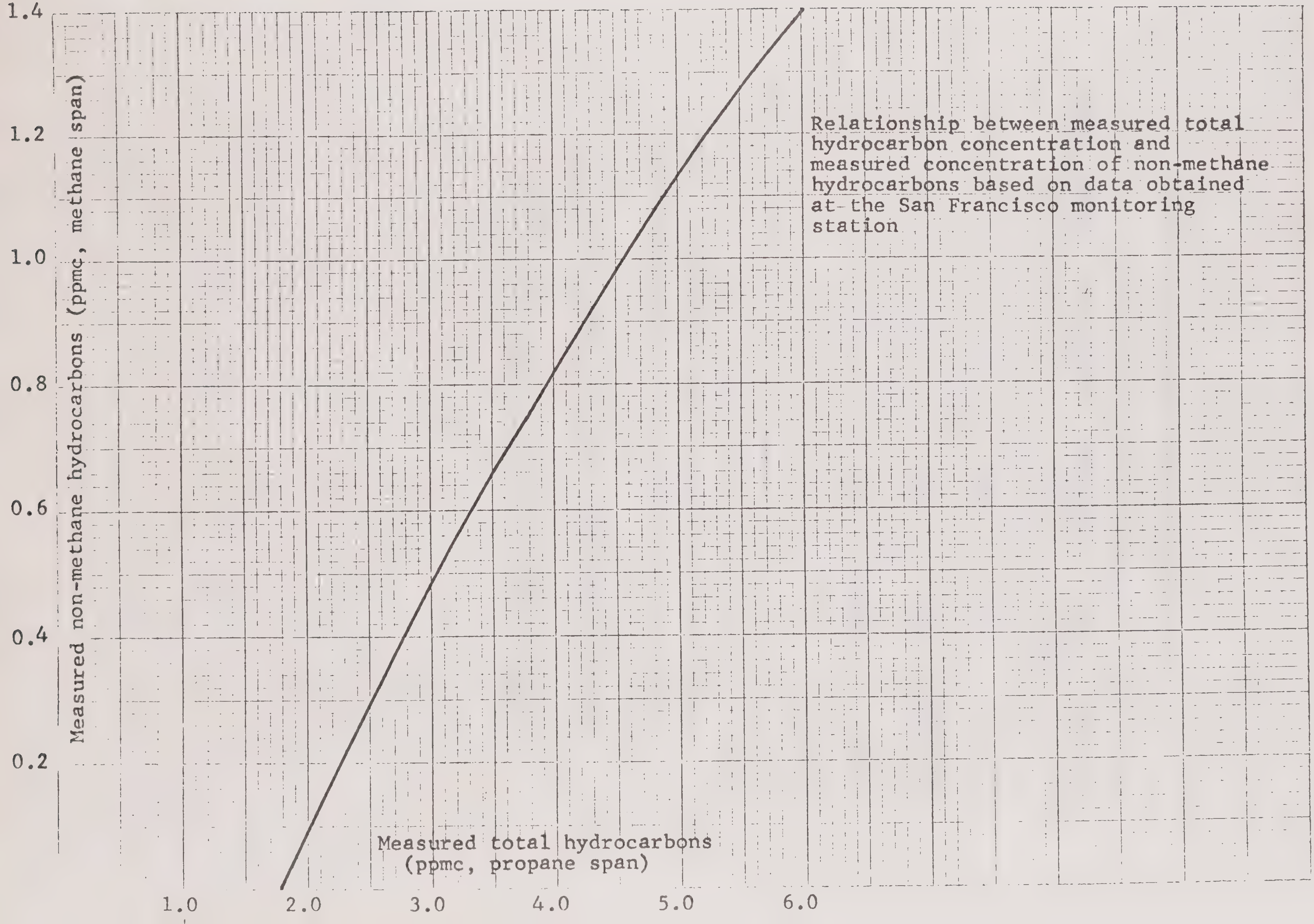
OXIDANT



NITROGEN DIOXIDE

Geographic distribution of annual standard geometric deviation for pollutant concentration in the San Francisco Bay Area based on four years of observation.

Figure C-6



1.4
1.2
1.0
0.8
0.6
0.4
0.2
Measured non-methane hydrocarbons (ppmc, methane span)
Relationship between measured total hydrocarbon concentration and measured concentration of non-methane hydrocarbons based on data obtained at the San Francisco monitoring station
Measured total hydrocarbons (ppmc, propane span)
1.0
2.0
3.0
4.0
5.0
6.0

Table C-7

DATA FOR MODELING CALIBRATION AND STATISTICAL ANALYSIS

Pollutant species	Raw Value	Calibrated value	Calibrated factor	Assumed standard geom. deviation
Carbon monoxide	1.69	2.02	x 1.20	1.9
Non-methane hydrocarbons	0.56	0.22	x 0.38	1.9
Sulfur dioxide	0.004	0.004	x 0.00	2.0
Suspended particulate	35	47	+ 12	1.8

Notes:

Values for gases are in units of parts per million by volume.

Values for particulates are in units of micrograms per cubic meter.

Raw and calibrated values apply to the downtown Santa Rosa grid square (UTM 525E 4254N, south west corner) and to base year.

Calibration factors and standard geometric deviations are assumed valid for all grid squares and all future years.

APPENDIX D

Technical Description of Oxidant Modeling

METHODS FOR OXIDANT ANALYSIS

The oxidant analysis applied a modified proportional rollback technique to determine the effect of future changes in pollutant emissions on oxidant concentrations. Although there are shortcomings in using proportional rollback techniques, it was the only method judged feasible for this study. The modifications made to the usual rollback analysis have made its application to this study reasonable and useful.

A basic problem in applying the rollback approach to a specific area, such as Sonoma County, is that oxidant concentrations are not only a function of emissions in Sonoma County but of emssions in other sections of the Bay Area. Furthermore, different areas in Sonoma County are affected differently by transported emissions. On one extreme, oxidant concentrations in various areas of Sonoma County can be assumed to be proportional to County emissions only. On the other extreme, oxidant concentrations in Sonoma County can be assumed to be proportional to emissions of the entire San Francisco Bay Area Basin. This analysis uses an approach between these two extremes, as described below.

The first step was to determine the weighting factors for estimating transport from county to county in the entire basin. The method for determining these factors is explained in Appendix C. The only alterations to that method used in the oxidant analysis are:

1) separating Sonoma County into three "boxes", based on the location of the three county oxidant monitoring station and

2) using the April-October frequencies of wind types because oxidant is a seasonal phenomenon that depends on solar radiation.

Once the weighting factors are determined, they are multiplied by the county concentrations to determine the concentration that is transported to the receptor box. These weighting factors are presented in Table C-1. The rows are the receptor boxes -- Santa Rosa, Petaluma and Sonoma -- while the columns are the source boxes. The source box concentration is multiplied by the appropriate weighting factor to determine its affect on any one of the receptor boxes.

This, then, defines the total non-methane hydrocarbon burden in the three areas of Sonoma County, and also estimates the relative importance of transport and local sources. The analysis so far has assumed a direct proportionality between non-methane hydrocarbons and oxidants. This assumption does present a basic problem of the proportional technique because oxidants are actually a complex funtion of non-methane hydrocarbons and nitrogen oxides. The remainder of the analysis will continue to assume a direct proportionality because it has been found to give a reasonably good approximation in the range of oxidant concentrations under consideration.

The total non-methane hydrocarbon burden for each area of Sonoma County, then, is assumed to be directly proportional to the annual mean oxidant concentration for each area. A lognormal statistical frequency distri-

bution used to represent base-year oxidant monitoring data for purposes of this analysis are recommended by R. I. Larsen (EPA, 1971). The magnitude of oxidant concentrations in this type of analysis is assumed to be proportional to the magnitude of pollutant sources (in this case, non-methane hydrocarbon box-model concentrations) and is represented by the mean concentration of the statistical distribution of hourly oxidant values. The variance of oxidant concentrations is proportional to meteorological factors and is defined by the standard geometric deviation of the statistical distribution. The latter is assumed to be invariant from base-year to any future year, which is a reasonable assumption if a representative base-year is selected.

The base-year oxidant concentration distributions for this analysis are actually an average of two years, 1973 and 1974, for Santa Rosa and Petaluma, and a one-year period, September 1974 - August 1975, for Sonoma. These data amounted to the only complete records available at the time of the study. The relevant parameters needed to define the statistical distribution were determined from the data and are as follows:

Table D-1

BASE-YEAR OXIDANT DISTRIBUTION PARAMETERS

	GEOMETRIC MEAN	STANDARD GEOMETRIC DEVIATION
Santa Rosa	0.023	1.55
Petaluma	0.026	1.55
Sonoma	0.033	1.55

Because the geometric mean is proportional to emission sources, any change in non-methane hydrocarbon emission rates in any sub-area of Sonoma County or other county can be evaluated for their effect on mean oxidant concentrations in a particular sub-area of Sonoma County by use of the following formula:

$$\frac{Cp}{X_1Y_1 + X_2Y_2 \ldots + X_nY_n} = \frac{Cf}{X_1Z_1 + X_2Z_2 \ldots + X_rZ_r}$$

where Cp = present geometric mean oxidant concentration

Cf = future geometric mean oxidant concentration

X_1 = weighting factors for a given county or area of Sonoma County

Y_1 = present box-model non-methane HC concentration of a given county or area of Sonoma County

Z_1 = future box-model non-methane HC concentration of a given county or area of Sonoma County

Once the future mean oxidant concentration has been determined, the lognormal frequency distribution can also be determined allowing calculation of maximum annual oxidant concentrations and number of times standard are exceeded. This can be accomplished graphically or by use of the following formulas that are defined by the lognormal distribution:

$$C_{max} = (MG)\ (SGD)^{Z_1}$$

$$Z_{(.09)} = \frac{\ln .09}{\ln(SGD)} - \frac{\ln(MG)}{\ln(SGD)}$$

where C_{max} = annual hourly oxidant concentration

SGD = standard geometric deviation

MG = geometric mean oxidant concentration

Z_1 = 3.81 - number of standard deviations from the annual hourly maximum oxidant concentration

$Z_{(0.9)}$ - number of standard deviations from the mean of the percentage frequency that the National Ambient Air Quality Standard for oxidants is exceeded.

Once the value of $X_{(.09)}$ has been determined, one must use a statistical table to find the percent frequency that it represents, such as Table 11 on page 30 of EPA publication AP-89, "A Mathematical Model for Relating Air Quality Standards," by R. I. Larsen. This percent frequency can then be used to multiply the total hours in a year to determine the number of hours the oxidant standard is exceeded.

The above formulas were applied to the baseyear MG and SGD parameters to check the validity of those parameters as well as the assumption of lognormality. The calculated annual hourly maximum concentration and number of times the standard was exceeded were within 90% agreement with the actual monitoring data.

APPENDIX E

Technical Description of Traffic Estimation Procedures

APPENDIX E - TECHNICAL DESCRIPTION OF TRAFFIC ESTIMATION PROCEDURES

OVERVIEW

One of the tasks in the study was the projection of air pollution emissions for each of the alternative development patterns. This appendix describes the procedure used to predict vehicular emissions for these alternatives and presents a brief discussion of the advantages and disadvantages of the selected approach.

The land use alternatives were represented by population, employment and land use information at 1-k^2 gridded detail. The subsequent tasks involved developing air pollution emissions at the 1-km^2 grid cell level from land use information for input to air quality models. The pollutants considered in the study were carbon monoxide, particulate matter, non-methane hydrocarbons, oxides of nitrogen and sulfur oxides. The hydrocarbon inventories were totaled for the Santa Rosa, Petaluma and Sonoma subbasins in the study area to facilitate the oxidant analysis.

ANALYSIS PROCEDURES

A multiple regression formulation was used to determine the relationship between different study variables and vehicular emission. Coefficients were determined by analyzing two cases where emissions were known; these coefficients, in turn, were used to predict emissions for the other land use alternatives.

The two alternatives that provided the input data were Base Year (1973) and Continuing Trends 478. Gridded emissions data were available for these conditions from previous work. The Base Year traffic data were compiled by the county from observations and traffic counts. The Continuing Trends 478 data were developed through modeling techniques by JHK and Associates at a detailed traffic zone level, with adjustments made by the County Engineer. These link loadings, consisting of average daily traffic and average speed, were then manually allocated to the appropriate grid cells and the information punched onto computer cards. The result was a 4000-card deck of all the traffic links by grid cell.

The gridded vehicle kilometer traveled was translated to gridded emissions using speed dependent emission factors from the Bay Area Air Pollution Control District.

The steps in the regression analysis procedure were as follows:

I. For Continuing Trends 478

1. Perform regression analysis on Continuing Trends 478 data to determine regression coefficients.

2. Use regression coefficients (Step 1) to predict emissions in each grid cell.

3. Compute residual emission by subtracting predicted emissions (Step 2) from the emissions developed from JHK traffic model and BAAPCD emissions factors.

II. For each Land Use Alternative

4. Use regression coefficients to predict emissions for each cell for each alternative.

5. Compute residual correction factor.

6. Add corrected residuals (Step 3 times Step 5) to each cell emission value (Step 4) to produce corrected emission value.

The remainder of this appendix details this procedure.

Regression Analysis

Considerable effort was devoted to investigation of the most significant variables to be included in the regressions. The variables that were most useful were total population per grid, total employment per grid, amount of land in commercial and medium density residential land uses per grid and the ratio of average daily traffic on major arteries to the distance of the cell from the major arteries.

The final form of the prediction equation used for CO was:

$$
\begin{aligned}
CO_{cell}(\text{kg/day}) = \; & .012 \times pop_{cell} \\
& +.16 \times f_1 \\
& +.069 \times emp_{cell} \\
& +1.91 \times \text{Commercial Suburban Acreage} \\
& +1.70 \times \text{Medium Density Residential Acreage} \\
& +1.61 \times \text{Commercial CBD Acreage} \\
& +1.06 \times \text{Freeway Dummy Variable} \\
& -11.6
\end{aligned}
$$

Table E-1 presents the coefficients for the other pollutants. The technique explains 68% of the variance for CO.

The primary reason the population, employment and land use variables were useful in the regression analysis was because they, or their equivalents, were key variables in the JHK traffic models. For example, the traffic model generates a high proportion of trips from commercial employment categories that the study had allocated to commercial land uses. Therefore, commercial land uses became a key variable in the regression analysis.

TABLE E-1

REGRESSION COEFFICIENTS

	CO	Particulate Matter	Non-methane Hydrocarbons	No_x	SO_x
$\text{Employment}_{\text{cell}}$	.069	.00185	.0116	.0223	.00181
$\text{Population}_{\text{cell}}$	.012	.00022	.00285	.00429	.00038
Commercial Suburban $\text{Acreage}_{\text{cell}}$	1.91	.0475	.294	.489	.0427
Medium Density Residential $\text{Acreage}_{\text{cell}}$	1.70	.051	.236	.516	.0400
Commercial City Centered $\text{Acreage}_{\text{cell}}$	1.61	.0342	.197	.270	.0248
Freeway dummy variable	1.06	.0358	.214	.501	.0380
$f_1$cell	.16	.0042	--	--	--
(Constant)	-11.66	-.147	1.84	6.00	.407

Another variable that proved successful was the relationship of traffic volume on the major traffic links to the distance from the grid cell to those links. This relationship was explained by:

$$f_{\ell} = \sum_{j=\text{ all major links}} \frac{(\text{loading on a traffic link})_j}{(\text{distance of grid to link})_j}$$

Specifically, f_{ℓ} is the summation of the ratios of the average daily traffic (ADT) of each major traffic link (roadways having greater than 10,000 ADT in 1973) to the distance between the grid cells to the link. The ADT on the major links was projected for the alternative development patterns by a proportionality to population and employment in nearby cities, using regression analysis supplemented by professional judgment.

Finally the use of dummy variables proved fruitful. Grids which contained major traffic links were assigned a value equivalent to their ADT; those not containing major links were given a 0.

Variables that were tested but which did not prove fruitful included the other land uses and the distance of the grid cell from all cities. On the assumption that one set of coeffficients was not sufficient to explain the variance for the entire county, the data were separated, or "stratified", by certain charactersitics, e.g. urban/rural, low/high emissions, proximity to freeways or city centers. Also an analysis was made of the logrithms of the variables, to demonstrate any multiplicative correlations, and of the differences between 1973 and 2000 variables. None of the above investigations produced any significant improvements in the variance explained.

Addition of Residuals

The existing pattern of emissions in the county shows large values in cells containing freeway links or within cities and often very low emissions in adjacent rural cells. The formula as set up, however, produces an emissions pattern that tends to smooth these features and does not account for the sharp differences between cells. A procedure of adding residuals was employed to adjust for the smoothing problem. Using Continuing Trends 478 with its "known" gridded emissions, the residual for each cell was determined by subtracting the predicted value from the actual value. This residual, multiplied by a correction factor, was then added to the cell's predicted value for each alternative.

Thus, when a cell contained especially large or small emissions, which were not represented by the regression formula (e.g. intersection of several arteries), the correction factor raised or lowered the emission value proportional to the difference between the actual Continuing Trends 478 values and the regression-predicted values. In this manner the underlying traffic structure was constrained to resemble the Continuing Trends 478 distribution of traffic, while the land use differences between the various alternatives were represented through the regression equation. This procedure was used to predict the Continuing Trends 478 values from the 1973 data and the comparison with the results of the traffic model for Continuing Trends 478 emissions was very good.

It was necessary that the above correction factor indicated activity differences between Continuing Trend 478 and the other alternatives and emphasized accuracy in the prediction of hot spots. The sum of the ADT's on the four largest traffic arteries was chosen as a correction factor to satisfy these criteria. The equation demonstrating the use of this factor is:

$$E_i = E_{i_{\text{regression}}} + (R_i \times CF)$$

Where E_i is the concentration in the $i^{\underline{th}}$ cell

$E_{i_{\text{regression}}}$ is the regression predicted concentration in the $i^{\underline{th}}$ cell

R_i is the CT478 residual

$$\left(= E_{i_{\text{CT478 "actual"}}} - E_{i_{\text{CT478 regression}}} \right)$$

and CF is the correction factor.

This technique, however, results in patterns that were forced to superficially resemble the Continuing Trends 478 pattern by the addition of the Continuing Trends 478 residuals. This was not considered too significant a restriction in certain particular cases (e.g., Santa Rosa Centered, Urban Centered) since these alternatives were basically similar (i.e., city centered); but other alternatives (e.g. Rural Disperesed, Suburban Dispersed) represented a more dispersed pattern of growth and were expected to be less accurately represented with this technique.

CONCLUSIONS

There were two main drawbacks to the use of the regression technique. First, it was unable to precisely predict emissions in grids between trip origins and destinations. Therefore, the technique would tend to under estimate total emissions associated with dispersed land use patterns relative to compact ones because the former would generate longer trips.

A second drawback of the regression technique was its inability to represent the effects of possible traffic control measures. The regression analysis was constrained by the traffic modeling assumptions made under the Continuing Trends 478 alternative. Therefore, similar assumptions had to be used for all alternatives thereby precluding new assumptions based, for example, on higher transit use or restricted car use.

In conclusion, the regression technique provided a good representation of the emissions patterns associated with most of the land use patters developed in the study. However, it was somewhat less accurate with the dispersed patterns and did not provide an adequate means to test traffic control measures.

APPENDIX F

Technical Description of the Water Quality Modeling

RUNOFF-QUALITY MODEL

An urban storm drainage model developed by WRE and used most recently in Seattle and an agricultural runoff model developed by WRE for EPA were meshed to create the ABAG Runoff-Quality Model. Following is a brief description of each model and references to reports providing a detailed discussion of those models.

Urban Storm Drainage Model

In October of 1971, under the sponsorship of the Environmental Protection Agency, a consortium of private contracts -- Metcalf and Eddy, Inc., the University of Florida, and Water Resources Engineers, Inc. -- presented a comprehensive mathematical model capable of representing urban stormwater runoff and combined sewer phenomena. The model was comprised of a series of individual sections or blocks which could be used either separately or in combination. The principal elements of the model are the runoff, transport, storage and receiving water blocks.

Subsequent to initial development, the various blocks of the model have been extensively developed and modified in further applications. In a major study of stormwater drainage for the City of San Francisco, the runoff block was updated to include revised concepts of gutter flow and the transport model was rewritten to develop a model capable of handling looped networks typical of sewers, plus irregular piping systems and surcharge.

The model developed for the City of San Francisco was used in the Seattle Metropolitan area. The Seattle version of the urban storm drainage model is the one WRE adapted to Sonoma County. The reader is referred to the program documentation and users guide for a detailed description of the model (1).

The model consists of four primary sections or blocks which are used to simulate the quality and quantity of flow from a wtershed, through a drainage system, and then to display the results.

Specifically, the blocks are:

1. Display Block - A graphical output routine for producing plots on the line printer.

2. Runoff Block - A set of computer routines which simulates quality and quantity of surface flow from watersheds plus routing tributary drainage channels and/or pipes.

3. Transport Block - A set of computer routines which dynamically routes flow through drainage systems.

4. Transport Quality Block - A computer routine which uses the flow simulation of the Transport Block to route quality constituents in drainage systems.

The Runoff Block is of primary interest in the ABAG study. Flow routing through combined sewer systems was not a part of the ABAG study.

The Runoff Block consists of a set of computer routines and appropriate data which will simulate the rainfall-runoff characteristics of an urban area. In the model flow is traced from the onset of rainfall to the watershed, through overland flow, and then to flow in the tributary channels. Water quality mass emissions are generated as they occur on the watershed surface.

Hydraulic flow is represented by the kinematic wave solution for flow across a plane surface. This rather simple approach is applied to a geometric representation of an urban area which includes the major hydrologic subunits of surface drainage. In the model each of the watershed subunits is treated as if it were completely independent of all others in the systme. This idealization is basic to the structure of the Runoff Model; when it is found that this is not a good approximation corrections must be made by changing watershed boundaries or creating new unit watersheds.

Rain falls directly on the pervious and impervious areas. On the former, some is lost by infiltration to the groundwater. After deducting losses, flow moves from the watersheds to the tributaries. The model assumes that the pervious and the impervious areas are separate within the watersheds, each of which drains into the adjacent tributary.

The quality of the surface runoff is important in the analysis of urban systems, and more than 20 water quality constitutents have been included in the Runoff Model. The contribution from each subarea for each constituent is determined by combination of land use and equivalent street-gutter length. These values must be specified for all subareas in the watershed.

The constitutive relationships for all quality parameters in the Runoff Model have been determined from observations of actual runoff quality in the Seattle Metropolitan area. These relationships were used in the ABAG study.

Agricultural Runoff Model

The model used to simulate runoff and washoff from nonurban areas in Sonoma County was developed by WRE in a project for the EPA. This model evolved from a series of modifications to urban storm runoff models. These modifications concerned the manner in which pollution loads were washed off and the addition of the capability to route pollutants through tributary channels. For details, the reader may find them in WRE's report (2) to EPA.

As presently structured, the Agricultural Runoff Model (subsequently called AGRUN) has the capability to simulate storm runoff hydrographs and pollutographs for up to 22 water quality parameters from agricultural watersheds. The watershed may be subdivided into as many as 200 subareas. For each subarea, the surface area, width and slope must be specified, plus the crop cover. The Manning n, surface depression storage, and Horton infiltration coefficients are entered as input data for each land use type.

The tributary drainage system may be subdivided into as many as 200 channels. The system must be dendritic in form. For each channel the length, invert slope, and Manning n are specified, plus appropriate cross section data. Cross sections may be triangular, trapezoidal or rectangular.

The user has the option of representing infiltration by the Horton equation alone, in which case interflow computations are neglected; or he may specify the additional data which will be used to compute the contribution of interflow to storm runoff. If the latter computation is desired, the following data are require for each subarea:

1. Number of soil layers above groundwater table.

2. Soils data for each layer, i.e.

    a. depth of layer,

    b. permeability coefficient,

    c. field capacity,

    d. saturation level, and

    e. present field capacity available at the beginning of the storm.

3. Constant baseflow (if any) from the watershed.

Computations of quality can be made for up to 22 constituents. The number desired is specified by the user. Constituents include:

1. Total suspended solids
2. Suspended solids (Non-settleable)
3. TDS
4. BOD
5. COD
6. Chlorides
7. SO4
8. Grease
9. Total coliforms
10. Fecal coliforms
11. Ammonia
12. Organic N
13. Nitrite and nitrate
14. Phosphate
15. Orthophosphate
16. Mercury
17. Copper
18. Zinc
19. Lead
20. Chromium
21. Cadmium
22. Arsenic

STREAM QUALITY MODEL -- QUAL-II

In 1971 Water Resources Engineers, Inc. added a great deal of simulation capability to an existing model known as QUAL-I, which simulated dissolved oxygen and a conservative constituent in streams. QUAL-I was developed in Texas by the Texas Water Development Board and a consultant, Frank D. Masch and Associates. QUAL-II was developed by WRE for the Environmental Protection Agency. QUAL-II has now been used by many people for simulating stream quality in rivers throughout the United States.

QUAL-II, in its most basic version, is a steady-state model of stream quality. It works best in moderately sized streams having flows that are a foot or more deep and that are contained within a well defined channel. It also simulates only aerobic conditions, so pollutional loads of BOD and/or ammonia must be small enough so that dissolved oxygen levels remain greater than zero. The model currently will continue to remove oxygen in response to BOD or nitrogenous loads even to the point of indicating negative concentrations of dissolved oxygen, which obviously could never occur. But the model remains useful in this regard, because it indicates rather dramatically where in a stream network such serious conditions might arise that dissolved oxygen would be completely depleted.

In addition to BOD and dissolved oxygen, QUAL-II simulates ammonia, nitrite, nitrate, chlorophyll _a_ (algae), orthophosphate (PO_4), coliform organisms and several conservative constituents which the user may specify. In this study, COD and suspended solids were modeled as conservative constituents, which obviously they are not; but the model cannot deal with these particular constituents otherwise.

The hydraulics of a stream are represented in the model with logarithmic relations between flow and depth and between flow and velocity, as follows:

$$H = a\,Q^b, \text{ and } V = c\,Q^d$$

where H is depth, Q is flow and V is velocity. The coefficients, a and c, and the exponents, b and d, must be determined for each reach of the stream, either from field data of flow, depth, and velocity, or from cross-sectional area information and solution of Manning's equation or the equivalent. The latter procedure was used.

The quality simulation operates as follows:

BOD is consumed by a first-order decay expression

$$BOD = BOD_o e^{-k_1 t}$$

where BOD is the amount of biochemical oxygen demand remaining after a travel time, t; BOD_o is the amount at the beginning of the time period; and k_1 is the stream decay rate for BOD. At steady-state, there will always be BOD_o entering each stream section and BOD will be left at the end, after the travel time has expired.

In the nitrogen system, ammonia is similarly decayed to nitrite, and very quickly nitrite is decayed to nitrate. In actuality these reactions are biological, not chemical; but as with BOD, the trick is merely to find the proper values for the coefficients. During the simulation ammonia is decreased and nitrite is increased according to the first-order reaction; then nitrite is increased according to a second reaction.

Nitrate (only) and phosphorus are used by algae then, along with light, to "grow" more algae. The algae in turn produce oxygen and use a little of it to keep themselves alive.

The conservative constituents such as salts, and in this case COD and suspended solids, are not changed in concentration by any reactions. They are increased or decreased only by additions to the stream or by dilution.

In essence, then, the stream is viewed as though it were timeless, with constant inflows at the headwaters and at waste discharge points and with constant inflows at the headwaters and at waste discharge points and with constant concentrations in these input quantities. So logically all the outflows will be the same and the concentrations will change downstream to a new constant value by decay or by dilution. Hence one could conceive the stream to be a solid string of cheese which can then be sliced into small pieces, each of which can be analyzed for its contents. This is pretty close to what the model does. The slices are called stream "elements", and the elements are grouped into similar packages called "reaches" wherein many physical, chemical and biological properties can be assumed to be constant. In the Laguna de Santa Rosa Basin 20 reaches and 176 elements were used. For a complete description of QUAL-II, the reader is referred to the program documentation manual (3).

The Petaluma River, like most estuaries, has a tidally affected downstream portion which is predominated in dry weather by the behavior of the downstream tide condition and affected only insignificantly by the upstream inflows of freshwater. To deal with this situation, the steady-state stream model, QUAL-II had to be altered somewhat. Three significant changes were made.

First, a tidally averaged depth for the estuarine reaches was added to the depth calculated on the basis of freshwater inflows alone. In the Petaluma River this ranged from 0 meters at the upstream end of reach 3 to about 4 meters at the mouth. The program reads data for the tidally averaged depth at the end of each estuarine reach and interpolates to find the depth to be added in each computational element.

Secondly, the expression in the program for the dispersion coefficient was altered for the tidally affected reaches to account for 1) tidally induced mixing and 2) salinity induced mixing. The new relationship is:

$$D_i = C_r\ (\nu_i + \sigma_{\nu_r})\ (h_i + \sigma_{h_r}) + (T\ \frac{Lo}{So})_r\ \frac{dS}{(dX)}_r$$

Where

D_i = mixing coefficient for element, i, L^2/T

C_r = a coefficient for reach, r, dimensionless

ν_i = average velocity in element, i, L/T

$\sigma_{\nu r}$ = standard deviation of velocity in reach, r, L/T

h_i = depth in element, i, L

σ_{h_i} = standard deviation of the depth in reach, r, L

$(T\ Lo/So)_r$ = a coefficient over the reference concentration gradient, $\frac{L^2}{T} \times \frac{L}{M/L^3}$

$(dS/dX)_r$ = salt concentration gradient in reach, r, $M/L^3/L$

Previous WRE work on San Francisco Bay and the Sacramento-San Joaquin Delta suggests that the values of C_r can range from 3.0 to 16.0, and T Lo/So can range from 750 to 50,000. The value of C_r used for the Petaluma River was 3.0. The values of T Lo/So ranged from 10,000 to 50,000. The values of dS/dX ranged from 1000 near the mouth to 5000 at the upstream end of the estuarine portion. This expression was calibrated with data for salinity obtained from the San Francisco Bay Regional Water Quality Control Board.

The third change in QUAL-II was the addition of a capability to read and then use the downstream, tailwater quality concentrations of all the constituents being simulated. This was necessary so the altered model could disperse or mix properly upstream in response to the salinity gradient. The modeled results for concentrations approach the values given for San Francisco Bay, which were determined from prior WRE simulation results.

MODEL ADAPTATION

A great deal of basic data was required in order to adapt the Runoff-Quality and QUAL-II Models to Sonoma County. Watersheds, channels and precipitation patterns unique to the Laguna and Petaluma Basins were defined for the Runoff-Quality Model. In addition to the length, width, and slope of each watershed, the infiltration characteristics and percentage of impervious area must be specified for the Runoff-Quality Model. QUAL-II requires a definition of the channels it simulates, the headwater inflows and qualities, and the flow rates and qualities of discharges to the channels represented by the QUAL-II Model.

Watershed and Channel Characteristics

One of the first tasks in the investigation was to define the hydrologic areas to be modeled within the Laguna de Santa Rosa and Petaluma River drainage areas. Three levels of detail were established for drainage areas. In descending order areawise, they are:

Basin
Waterhsed
Subarea

Figures VI-16 and VI-28 show the subareas and channels for the Laguna and Petaluma Basins, respectively. After the hydrologic subareas were identified, the ABAG one kilometer grid system for Sonoma County was overlaid on the subarea map and the boundary of each subarea was modified to follow the grid system. This procedure was adopted so that land use data prepared by ABAG on one kilometer squares could be aggregated directly for the Runoff-Quality Model. Some degree of accuracy in terms of the area of subareas is sacrificed by using this procedure; however, this loss of accuracy is offset by being able to use the land use data directly.

The Runoff-Quality Model requires the length, width and slope of each subarea. This information was taken off the U.S.G.S. 7-1/2 minute quad sheets. Tables F-1 and F-2 show these watershed characteristics for the Laguna and Petaluma Basins, respectively.

The surface infiltration rates of the soils within Sonoma County were measured by the USDA Soil Conservation Service in 1964 and are appropriate for use in the Runoff-Quality Model. There were seven permeability (infiltration) groups. Maps were then made by ABAG, using the SCS data, indicating one of the three infiltration rate groups (high, medium, or low) for each soil type.

As land use becomes more intese infiltration rates are reduced from the natural rates (i.e. those indicated for Parks/Dedicated Open Space, Agriculture, Unused Land). This reduction in rates is due to a greater compaction of the surface soils as a result of clearing and grading operations associated with the construction of homes, buildings, industrial facilities, etc. Infiltration rates and the maximum allowable infiltration are shown in Table F-3.

Both the initial (maximum) infiltration rates and base (minimum) infiltration rates are used in the Runoff-Quality Model. The rate of decay is 4.14/hr for all soil types. Infiltration of rainfall on impervious areas is to be considered negligible.

The ABAG staff made several checks on the percentage of impervious area in Rohnert Park, Cotati, Sebastopol, Santa Rosa, Petaluma and other communities in Sonoma County. Aerial photographs of the above areas were used to estimate impervious areas associated with residential, commercial and industrial land uses. These checks together with the results of the other investigations were then used to finalize values for use in the Runoff-Quality Model. The values used are presented in Table F-4.

TABLE F-1

WATERSHED DATA--LAGUNA BASIN

WATERSHED DATA FOR BASIN NO. 1, LAND USE PLAN - SRC478

INT NUM	SUBAREA NUMBER	CHANNEL NUMBER	WIDTH (M)	AREA (KM2)	SLOPE (M/M)	PRCNT IMP	MANNING N IMP	MANNING N PERV	DEP STOR (MM) IMP	DEP STOR (MM) PERV	INFL RT (MM/HR) MAX	INFL RT (MM/HR) MIN	MAXIMUM INFL(MM)	HYET NO	LND USE, PRCNT RES	LND USE, PRCNT COM	LND USE, PRCNT IND	LND USE, PRCNT OPEN
1	1001	1001	6984.	9.	.006	8.7	.013	.200	1.588	6.350	41.93	2.29	190.56	2	2	0	2	95
2	1002	1005	6968.	9.	.027	10.1	.013	.200	1.587	6.350	44.84	2.99	208.13	3	2	0	3	93
3	1003	1006	12006.	18.	.010	8.5	.013	.200	1.588	6.350	46.49	3.34	217.27	3	0	1	1	96
4	1004	1003	9206.	12.	.006	8.8	.013	.200	1.588	6.350	44.65	2.85	205.43	3	5	0	1	92
5	1005	1007	10461.	14.	.005	6.0	.013	.200	1.588	6.350	43.54	3.81	217.71	4	0	0	0	99
6	1006	1002	5424.	7.	.006	30.9	.013	.200	1.588	6.350	44.88	2.48	200.41	2	1	4	22	71
7	2001	2002	11973.	12.	.006	30.0	.013	.200	1.588	6.350	45.18	3.75	220.61	2	1	0	25	72
8	2002	2001	5987.	11.	.006	10.4	.013	.200	1.588	6.350	47.14	3.27	217.69	2	5	1	1	91
9	2003	2003	10445.	15.	.200	7.7	.013	.200	1.588	6.350	45.24	4.10	226.02	3	1	1	0	97
10	2004	2004	13551.	19.	.200	6.0	.013	.200	1.588	6.350	50.80	5.08	254.00	4	0	0	0	99
11	2005	2005	7226.	22.	.240	6.0	.013	.200	1.588	6.350	49.88	4.62	244.76	4	0	0	0	99
12	2006	2006	15852.	24.	.230	6.0	.013	.200	1.588	6.350	49.32	4.34	239.18	5	0	0	0	99
13	2007	2007	16335.	29.	.140	6.0	.013	.200	1.588	6.350	50.10	4.73	246.99	5	0	0	0	99
14	3001	3001	6695.	18.	.002	14.8	.013	.200	1.588	6.350	45.02	2.60	202.52	1	7	0	7	84
15	3002	3005	5987.	11.	.014	58.2	.013	.200	1.588	6.350	40.51	2.96	197.66	2	15	8	42	33
16	3003	3004	8868.	14.	.036	28.8	.013	.200	1.587	6.350	40.78	2.59	192.63	2	44	7	0	46
17	3004	3002	15241.	15.	.002	50.7	.013	.188	1.587	5.972	36.00	2.11	170.60	1	46	17	11	21
18	3005	3008	9399.	10.	.026	26.8	.013	.200	1.588	6.350	45.48	3.86	225.21	2	41	3	2	51
19	3006	3011	6824.	11.	.080	19.2	.013	.200	1.588	6.350	42.27	3.48	209.76	3	42	3	0	54
20	3007	3010	7693.	16.	.130	10.3	.013	.200	1.588	6.350	44.48	3.40	213.64	3	13	1	0	85
21	3008	3007	15241.	14.	.110	22.7	.013	.200	1.588	6.350	48.33	4.57	240.43	2	20	3	2	72
22	3009	3006	12408.	20.	.110	14.1	.013	.200	1.588	6.350	44.72	4.00	223.34	2	15	2	0	82
23	3010	3015	7210.	22.	.100	6.7	.013	.200	1.588	6.350	43.51	3.50	212.92	3	1	0	0	98
24	3011	3014	8980.	21.	.170	10.5	.013	.200	1.588	6.350	49.38	4.72	245.19	3	8	1	1	88
25	3012	3013	14983.	35.	.160	6.0	.013	.200	1.588	6.350	50.07	4.72	246.74	5	0	0	0	99
26	4001	4001	6679.	7.	.100	8.7	.013	.200	1.588	6.350	49.30	4.33	239.03	2	0	0	1	98
27	4002	4001	3090.	7.	.027	9.2	.013	.200	1.588	6.350	42.99	2.36	194.10	2	7	0	1	90
28	4003	4002	3621.	14.	.005	6.8	.013	.200	1.588	6.350	44.90	2.64	202.92	2	0	0	0	98
29	4004	4003	4120.	8.	.028	8.0	.013	.200	1.588	6.350	43.62	2.40	196.21	2	1	0	1	96
30	4005	4003	4281.	20.	.005	12.2	.013	.200	1.588	6.350	40.01	2.16	184.17	2	13	0	2	83
31	4006	4004	9302.	18.	.023	17.3	.013	.200	1.588	6.350	36.67	1.94	173.05	2	21	3	2	72
32	4007	4004	4812.	26.	.004	23.0	.013	.200	1.588	6.350	41.85	2.28	190.30	1	19	2	10	67
33	4008	4005	11362.	22.	.039	8.0	.013	.200	1.588	6.350	42.92	3.11	205.51	2	4	0	0	94
34	4009	4006	5601.	13.	.014	8.2	.013	.200	1.588	6.350	44.85	3.75	219.78	2	6	0	0	93
35	4010	4007	4619.	17.	.002	24.5	.013	.200	1.588	6.350	39.70	2.14	183.13	1	36	2	8	52
36	4011	4008	7242.	7.	.002	7.4	.013	.200	1.588	6.350	34.68	1.80	166.39	1	5	0	0	94
37	4012	4012	13438.	44.	.009	19.5	.013	.200	1.588	6.350	35.68	2.32	176.72	1	17	5	3	73
38	4013	4009	8256.	35.	.004	14.9	.013	.200	1.588	6.350	38.05	2.65	187.14	2	15	2	3	78
39	4014	4011	12408.	12.	.100	6.8	.013	.200	1.588	6.350	49.23	4.80	246.09	2	1	0	0	97
40	4015	4013	14484.	10.	.080	6.0	.013	.200	1.588	6.350	46.74	4.37	233.68	4	0	0	0	100

TOTAL NUMBER OF SUBCATCHMENTS, 40

TOTAL TRIBUTARY AREA (KM2), 667.22

TABLE F-2

WATERSHED DATA--PETALUMA BASIN

WATERSHED DATA FOR BASIN NO. 2, LAND USE PLAN = SRC478

INT NUM	SUBAREA NUMBER	CHANNEL NUMBER	WIDTH (M)	AREA (KM2)	SLOPE (M/M)	PRCNT IMP	MANNING N IMP	MANNING N PERV	DEP STOR (MM) IMP	DEP STOR (MM) PERV	INFL RT (MM/HR) MAX	INFL RT (MM/HR) MIN	MAXIMUM INFL(MM)	HYET NO	LND USE, PRCNT RES	COM	IND	OPEN
1	1001	1004	3962.	7.	.035	10.7	.013	.200	1.588	6.350	33.34	2.01	166.45	1	1	1	3	93
2	1002	1002	5791.	7.	.018	6.1	.013	.200	1.588	6.350	30.48	1.52	152.40	1	0	0	0	99
3	1003	1005	11582.	7.	.010	16.5	.013	.200	1.588	6.350	30.48	1.52	152.40	1	21	0	5	72
4	1004	1007	4267.	8.	.005	35.9	.013	.200	1.588	6.350	30.48	1.52	152.40	1	38	7	13	40
5	1005	1008	4572.	14.	.030	21.8	.013	.200	1.588	6.350	41.98	3.17	204.20	1	34	5	0	60
6	1006	1003	10973.	21.	.020	6.0	.013	.200	1.588	6.350	36.29	2.54	181.43	3	0	0	0	99
7	1007	1009	10973.	7.	.010	22.5	.013	.200	1.588	6.350	30.48	1.52	152.40	1	40	4	1	53
8	1008	1011	4267.	14.	.014	17.9	.013	.200	1.588	6.350	35.31	2.36	176.38	1	9	5	4	80
9	1009	1006	6401.	12.	.150	6.0	.013	.200	1.588	6.350	45.72	4.19	228.60	5	0	0	0	99
10	1010	1010	15240.	13.	.100	6.0	.013	.200	1.588	6.350	36.73	2.62	183.66	5	0	0	0	99
11	1011	1018	6096.	17.	.030	10.0	.013	.200	1.588	6.350	49.80	4.59	244.11	3	9	0	1	88
12	1012	1017	10668.	25.	.020	10.2	.013	.200	1.588	6.350	49.14	4.52	241.55	3	0	0	3	94
13	1013	1015	11582.	15.	.015	9.6	.013	.200	1.588	6.350	42.53	3.60	212.15	3	3	1	1	93
14	1014	1014	8534.	13.	.033	6.7	.013	.200	1.588	6.350	35.20	2.35	176.02	4	0	0	0	99
15	1015	1016	10973.	9.	.025	7.8	.013	.200	1.588	6.350	32.78	1.93	163.91	4	1	1	0	97

TOTAL NUMBER OF SUBCATCHMENTS, 15

TOTAL TRIBUTARY AREA (KM2), 188.78

Table F-3

INFILTRATION RATES AND MAXIMUM POSSIBLE INFILTRATION

Land Use	Infiltration Rate Soil Group	Infiltration Rates, mm/hr Maximum	Minimum	Maximum Possible Infiltration, mm
Residential Light	High	45.7	2.5	203.2
	Medium	30.5	1.5	152.4
	Low	30.5	1.5	152.4
Residential Medium				
Residential Heavy	High	30.5	1.5	152.4
Commercial Centered	Medium	30.5	1.5	152.4
Commercial Suburban	Low	30.5	1.5	152.4
Industrial				
Grazing/Open	High	50.8	5.1	254.0
Agricultural -- Field/ Truck Crops	Medium	45.7	2.5	203.2
Agricultural -- Vineyards/ Orchards	Low	30.5	1.5	152.4

Table F-4

PERCENT IMPERVIOUS AREAS

Land Use Category	Percentage of Impervious Area
Residential Light	30
Residential Medium	65
Residential Heavy	80
Commercial Centered	95
Commercial Suburban	90
Industrial	98
Grazing/Open	6
Agricultural Field	6
Agricultural Vineyard	6

In order to obtain channel geometry for representation in both the Runoff-Quality Model and QUAL-II, it was necessary to make field measurements in both the Laguna and Petaluma River Basins. Sixty stations were visited in the Laguna Basin and 20 stations were visited in the Petaluma Basin by the ABAG staff. At each station, the cross-sectional area of the channel was recorded along with the field party's estimate of channel roughness conditions. Length and slopes of channels were taken off the U.S.G.S. 7-1/2 minute quad sheets. Tables F-5 and F-6 show the channel characteristics for the Laguna and Petaluma Basins, respectively.

Precipitation

The Environmental Data Service of the National Oceanic and Atmospheric Administration publishes hourly precipitation data each month for two continuous recording rain gages in the study area. They are Sebastopol and Petaluma Fire Station. The Sonoma County Water Agency has a continuous recording gage at the County Administration Building in Santa Rosa. There are several other rain gages in the Laguna and Petaluma Basins but none are continuous recording units.

Historical precipitation in Santa Rosa was reviewed and on the basis of precipitation in 1966, a "typical" year insofar as total annual rainfall and monthly distribution, a typical winter storm was developed and used in the wet weather simulations. Figure F-1 shows rainfall for 1966 at Santa Rosa. The typical winter storm produced 2.45 cm of precipitation over a 4-hour period. The assumption was made that the typical winter storm would produce total rainfall over the four hour period in proportion to the mean annual rainfall. Consequently, the 2.45 cm of rainfall produced by the typical storm at Santa Rosa correlates to Santa Rosa's mean annual rainfall of about 76.2 cm (30 in). For subareas having annual totals greater (or less) than 76.2 cm the

TABLE F-5

CHANNEL DATA--LAGUNA BASIN

DRAINAGE CHANNEL INPUT DATA FOR BASIN NO. 1

INT NUM	CHAN NUM	CHAN CONV	WIDTH (M)	LENGTH (M)	SLOPE (M/M)	SIDE SLOPES LEFT	SIDE SLOPES RIGHT	MANNING N	DEPTH (M)	V FULL (MPS)	Q FULL (CMS)
1	1001	4014	10.67	3536.	.00300	.2	.2	.050	4.57	2.08	109.065
2	1002	1001	4.57	1951.	.00300	.0	.0	.060	2.44	1.02	11.365
3	1003	1001	9.14	6706.	.00400	.2	.2	.040	1.52	1.76	25.361
4	1004	1001	13.72	1219.	.00100	.0	.0	.040	1.22	.81	13.531
5	1005	1004	4.57	2926.	.00400	.3	.3	.050	1.83	1.35	12.418
6	1006	1004	7.62	5486.	.00400	.3	.3	.050	1.22	1.23	12.042
7	1007	1003	5.18	2134.	.02500	.0	.0	.040	1.52	3.85	30.372
8	2001	2008	4.57	4877.	.00300	.3	.3	.040	1.22	1.22	7.245
9	2002	2008	76.20	5364.	.00300	.3	.3	.040	1.52	1.77	207.166
10	2003	2002	27.43	5486.	.00500	.2	.2	.040	2.74	3.10	238.109
11	2004	2003	16.76	7315.	.01200	.3	.3	.040	2.74	4.56	221.178
12	2005	2004	3.05	4877.	.02400	.3	.3	.040	2.74	4.32	44.226
13	2006	2004	18.29	8230.	.00700	.5	.5	.040	2.44	3.32	158.150
14	2007	2006	15.24	6096.	.02000	.3	.3	.040	1.22	3.70	70.591
15	2008	4001	91.44	2256.	.00300	.3	.3	.040	1.52	1.78	249.109
16	3001	4002	13.72	5334.	.00300	2.5	2.5	.040	3.96	2.64	246.720
17	3002	3001	13.72	6401.	.00300	2.5	2.5	.040	3.96	2.64	246.720
18	3003	3001	6.10	2438.	.00400	1.0	1.0	.040	3.05	2.42	67.465
19	3004	3003	6.10	6553.	.01000	1.0	.3	.040	1.52	2.65	28.511
20	3005	3003	9.14	4877.	.00400	.5	.5	.040	.91	1.35	11.811
21	3006	3002	4.57	10058.	.00800	.3	.3	.040	1.22	1.99	11.830
22	3007	3002	3.05	9144.	.03000	.3	.3	.080	1.52	1.97	10.637
23	3008	3016	4.88	4420.	.00500	.5	.5	.040	3.66	2.69	66.023
24	3009	3016	9.14	1524.	.00500	1.0	1.0	.040	1.52	2.01	32.611
25	3010	3009	7.62	3658.	.00900	.0	.5	.040	1.22	2.29	22.102
26	3011	3009	4.57	2743.	.02000	1.0	1.0	.050	1.52	2.91	27.080
27	3012	3008	3.66	1829.	.01200	1.0	1.0	.040	3.05	3.85	78.630
28	3013	3012	4.57	5791.	.02000	.3	.3	.040	3.05	4.73	80.407
29	3014	3008	15.24	4572.	.00800	.5	.5	.040	.91	1.98	28.361
30	3015	3006	5.49	3658.	.01400	1.0	1.0	.040	.91	2.39	13.975
31	3016	3002	7.62	3962.	.00500	.5	.5	.040	3.66	2.99	102.969
32	4001	4014	121.92	3048.	.00030	2.0	.3	.040	3.05	.88	336.540
33	4002	4001	121.92	2743.	.00030	2.0	.3	.040	3.05	.88	336.268
34	4003	4002	21.34	4572.	.00030	.0	.0	.040	3.05	.77	50.074
35	4004	4003	13.72	7925.	.00060	.5	.5	.030	3.05	1.41	65.375
36	4005	4004	15.24	3536.	.00200	1.0	1.0	.060	1.52	.89	22.765
37	4006	4004	9.14	5791.	.00050	2.0	2.0	.040	3.05	.90	41.769
38	4007	4004	9.14	3353.	.00100	.0	.0	.040	1.83	.94	15.801
39	4008	4006	60.96	3353.	.00040	1.0	1.0	.060	1.52	.43	40.838
40	4009	4008	24.38	3200.	.00100	1.0	1.0	.040	1.83	1.09	52.325
41	4010	4009	18.29	1524.	.02000	1.0	1.0	.040	.91	3.15	55.327
42	4011	4010	6.10	1372.	.18000	1.0	1.0	.040	1.52	11.41	132.539
43	4012	4006	9.14	8230.	.00400	.0	.0	.040	3.05	2.36	65.913
44	4013	4012	6.10	2743.	.03000	.3	.3	.050	1.52	3.65	36.694
45	4014	9099	182.88	4877.	.00040	2.0	2.0	.040	3.05	1.02	589.957

TOTAL NUMBER OF CHANNELS, 45

TABLE F-6

CHANNEL DATA--PETALUMA BASIN

DRAINAGE CHANNEL INPUT DATA FOR BASIN NO. 2

INT NUM	CHAN NUM	CHAN CONN	WIDTH (M)	LENGTH (M)	SLOPE (M/M)	SIDE SLOPES LEFT	SIDE SLOPES RIGHT	MANNING N	DEPTH (M)	V FULL (MPS)	Q FULL (CMS)
1	1001	1099	30.48	1219.	.00100	1.0	1.0	.040	3.05	1.50	153.317
2	1002	1001	7.62	3962.	.00300	.5	.5	.040	1.52	1.51	19.296
3	1003	1002	3.05	2286.	.00400	.3	.3	.040	3.05	1.83	21.247
4	1004	1001	27.43	1372.	.00100	1.0	1.0	.040	3.05	1.49	138.070
5	1005	1004	10.67	4267.	.01000	.3	.3	.040	1.52	2.85	48.054
6	1006	1005	6.10	4267.	.04000	.3	.3	.050	1.52	4.21	42.370
7	1007	1004	24.38	1829.	.00100	.3	.3	.040	3.05	1.46	111.609
8	1008	1007	22.86	2743.	.00100	1.0	1.0	.040	3.05	1.46	115.273
9	1009	1008	10.67	4877.	.01000	.3	.3	.050	1.52	2.28	38.444
10	1010	1009	6.10	4267.	.04000	1.0	1.0	.050	1.52	4.30	49.984
11	1011	1008	15.24	5486.	.00200	.3	.3	.050	3.05	1.55	76.874
12	1012	1011	6.10	1829.	.00200	.5	.5	.040	3.05	1.65	38.414
13	1013	1012	4.57	1067.	.00400	1.0	1.0	.040	1.52	1.63	15.138
14	1014	1013	4.57	4115.	.02000	.3	.3	.040	1.52	3.48	26.309
15	1015	1012	9.14	4877.	.00400	1.0	1.0	.040	1.52	1.79	29.168
16	1016	1015	4.57	3993.	.02000	.7	.7	.050	1.52	2.89	24.662
17	1017	1011	7.62	4328.	.00300	.3	.3	.050	1.52	1.19	14.520
18	1018	1011	7.62	4267.	.00300	.3	.3	.050	1.52	1.20	14.714

TOTAL NUMBER OF CHANNELS, 18

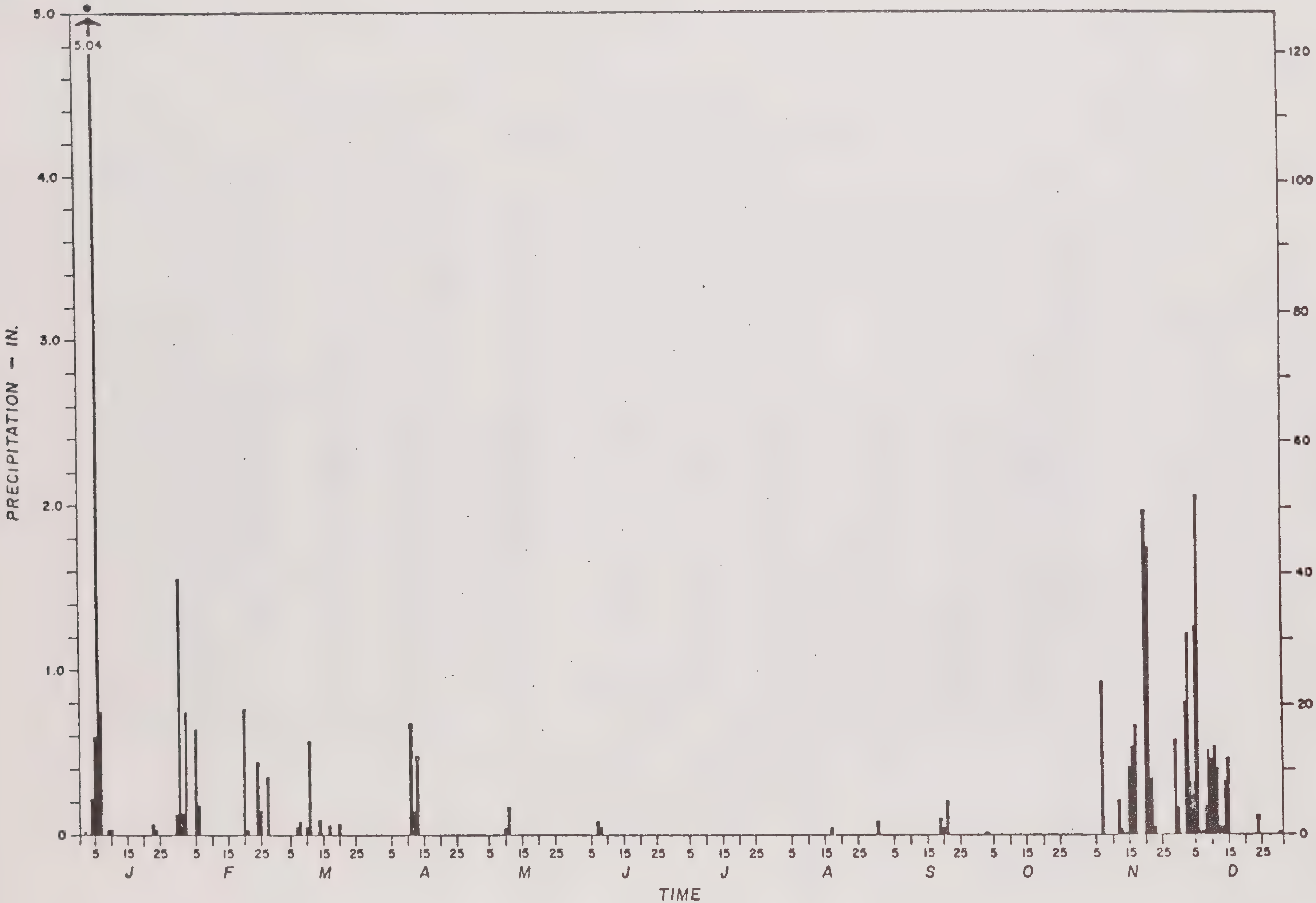


Figure F-1

HISTORICAL PRECIPITATION FOR 1966 AT SANTA ROSA

Santa Rosa rainfall was increased (or decreased) in direct relationship to the annual rainfall. For example, a subarea having an annual rainfall of 114.3 cm would receive 50 percent more rainfall during a storm than would a subarea with an average annual rainfall of 76.2 cm. This annual rainfall relationship is used by the Sonoma County Water Agency.

Five hyetographs were prepared based on mean annual rainfall and the appropriate hyetograph was assigned to each subarea. These assignments are given in Table F-1 and F-2. The intensity of rainfall at 30 minute intervals is given for each of the five hyetographs used in the Laguna and Petaluma Basins in Table F-7.

Headwater Flows and Point Source Discharges

Figures VI-3 and VI-9 show the QUAL-II stream network setup for the Laguna and Petaluma Basins. Flows and their qualities are required for the headwaters of the networks and the point source (STP) discharges. In dry weather there is almost no flow in the headwaters of the Laguna de Santa Rosa and its main tributaries, Windsor, Mark West and Santa Rosa Creeks. There is no flow in the upper reaches of the Petaluma River. Consequently, it was necessary to assume a small flow (0.1 m^3/sec) at the headwaters in order to have some water flowing in the upper elements. It was also necessary to make assumptions as to the quality of the headwater flows. Obviously, these assumptions complicate the task of calibrating the model. A trial and error procedure was required to set headwater flows and qualities so that the model could come close to simulating the observed quality downstream. This is discussed later in this appendix.

The point source discharges did not present much of a problem insofar as obtaining flow rates and effluent qualities. The Regional Water Quality Control Boards have records of sewage treatment plant flows and qualities and these records were used in calibrating the model. Under future levels of development, the recently completed Basin Plans were used to determine the location of sewage treatment plants. Flow rates were estimated by multiplying population by the historical per capita wastewater flows for the area and effluent qualities were based on actual discharge permit conditions or theoretical effluent qualities associated with various treatment levels.

KEY MODEL VARIABLES

The Runoff-Quality Model estimates the washoff loads from urban areas and rural areas for a single storm event. These washoff loads are then transported through the model channel system. The manner in which the pollution load available for washoff is estimated is described in the following pages.

Table F-7

DISTRIBUTION OF RAINFALL USED IN WET WEATHER SIMULATIONS

	Intensity at 30 minute intervals, mm/hr.							
Hyetograph	½ hr.	1 hr.	1½ hrs.	2 hrs.	2½ hrs.	3 hrs.	3½ hrs.	4 hrs.
Laguna Basin								
No. 1	2.79	3.56	4.57	18.29	7.11	5.08	4.06	3.30
No. 2	3.30	4.06	5.33	21.34	8.38	5.84	4.83	3.81
No. 3	3.81	4.83	6.10	24.38	9.40	6.86	5.33	4.32
No. 4	4.32	5.33	6.86	27.43	10.67	7.62	6.10	5.08
No. 5	4.57	5.84	7.62	30.48	11.94	8.38	6.86	5.59
Petaluma Basin								
No. 1	2.29	3.05	3.81	15.20	5.84	4.32	3.30	2.79
No. 2	2.79	3.56	4.57	18.29	7.11	5.08	4.06	3.30
No. 3	3.30	4.06	5.33	21.34	8.38	5.84	4.83	3.81
No. 4	3.81	4.83	6.10	24.38	9.40	6.86	5.33	4.32
No. 5	4.32	5.33	6.86	27.43	10.67	7.62	6.10	5.08

Urban Areas

Pollutants in developed areas accumulate on impervious surfaces and are washed off with the next storm. The key variable in the Runoff-Quality Model accounting for the pollution load in urban areas available for wasoff is the accumulation of dust and dirt. The daily rate of the buildup of dust and dirt per unit length of curb and gutter variable by land use is given in Table F-8.

Table F-8

BUILDUP OF DUST AND DIRT

Land Use	Curb and Gutter, meters/hectare	Rate, kilograms/ meter/day	Accumulation kilograms/hectare/ day
Residential Light	150.57	0.006	0.90
Residential Medium	225.86	0.009	2.03
Residential Heavy	301.14	0.016	4.82
Commercial Centered	301.14	0.024	7.23
Commercial Suburban	301.14	0.024	7.23
Industrial	225.86	0.33	7.45

All water quality parameters are expressed as a function of the accumulation of dust and dirt variable by land use. Table F-9 shows the relationship of the eight parameters modeled to dust and dirt.

The total accumulation of pollutants in urban areas available for washoff is dependent on the number of dry days preceeding the storm. Referring back to Figure F-1, the average interval between storms during 1966 in the Santa Rosa area was about 20 days. All wet weather simulations which are made to compare the effects of the various land use alternatives on wet weather quality were made with 20 days of buildup in urban areas.

NONURBAN AREAS

The Universal Soil Loss Equation is used to predict total erosion from a nonurban land area. The universal soil loss equation states that (5):

$$A = (R)*(K)*(L)*(C)*(P)$$

Where A is the soil loss per unit area in tons/acre/time step,
R represents the rainfall factor,
K is the soil erodibility factor,
L represents the slope length gradient ratio
C is the cropping management factor, and
P is the erosion control practice factor.

R, in turn, is given by

$$R = EI = \Sigma_i[(9.16 + 3.31 \log X_i)D_i]I$$

Where E represents the rainfall energy in hundreds of foot-tons/acre,
i is the rainfall hyetograph interval,
X_i represents the rainfall intensity during time interval,
D_i is the inches of rainfall during the time interval, and
I is the maximum average 30 minute intensity of rainfall.

The value of L is given by

$$L = \lambda^{1/2}(0.0076 + .0053S + .00076S^2)$$

Where λ is the length in feet from the point of origin of flow to the point at which sedimentation occurs or at which flow enters some defined channel, and
S is the average percent slope over the runoff length.

Table F-9

RELATIONSHIP OF WATER QUALITY PARAMETERS TO DUST AND DIRT

Parameter	Parameter/Dust and Dirt, mg/g					
	RL	RM	RH	CC	CS	I
Total Suspended Solids	340	340	250	445	445	249
Nonsettleable Soilds	180	180	280	240	240	176
BOD	35.7	35.7	53.1	35.9	35.9	14.0
Oil and Grease	45.1	45.1	78.6	30.2	30.2	35.4
Fecal Coliforms*	82×10^3	82×10^3	190×10^3	0.82×10^3	0.82×10^3	7.7×10^3
Total Nitrogen	7.51	7.51	5.12	6.32	6.32	4.52
Total Phosphorus	1.06	1.06	1.08	0.65	0.65	0.69
Total Heavy Metals	2.16	2.16	2.28	2.26	2.26	1.90

*Organisms/g - The number of fecal organisms/gram of dust and dirt was determined by dividing the number of organisms in the runoff samples by the weight of total solids (dust and dirt) in the samples.

The remaining variables (K, C, and P) are empirical in nature and are generally obtained from a table or monograph. For K, the Sonoma County Soil Survey (4) provided the basic information on the five soil parameters that constitute this term. The parameters are:

1. % silt + very fine sand
2. % sand > 0.10 mm
3. Organic matter content
4. Soil structure
5. Permeability

Six soil types may be used to approximate the soils in Sonoma County and an average value for each parameter was calculated and then used in a monograph to determine a K value of 0.20 for Sonoma County. The crop management factor "C" used was as follows:

Grazing and Open	0.0002
Agricultural - Orchards/Vineyards	0.0020
Agricultural - Truck/Field Crops	0.0016

The Runoff-Quality Model solves the Universal Soil Loss Equation giving total suspended solids washed off each subarea within each watershed. All other constituents are computed as a constant fraction of total suspended solids. The fractions are variable by constituent and constant by land use type.

The surface loading rates for constituents other than suspended solids are based on the mass emissions of nonpoint source pollutants provided in the San Francisco Bay Basin Plan (6). The ratios of several constituents to suspended solids for Sonoma County are:

(1) $\frac{\text{BOD}}{\text{TSS}} = 3.2$

(2) $\frac{\text{Nitrogen}}{\text{TSS}} = 2.6$

(3) $\frac{\text{Phosphorus}}{\text{TSS}} = 0.2$

(4) $\frac{\text{Oil \& Grease}}{\text{TSS}} = 2.2$

(5) $\frac{\text{Total Heavy Metals}}{\text{TSS}} = 0.3$

Two other constituents, including settleable solids and fecal coliform, are of interest in the ABAG investigation and the loading rates for these were adopted from work WRE did in Iowa where the nonurban portion of the runoff was calibrated and verified. The preceeding ratios developed from the Bay Basin work are in good agreement with the same ratios used in Iowa. Table F-10 shows the surface loading rates used in the ABAG investigation for the three classes of nonurban land use provided for each alternative.

Table F-10

NONURBAN LAND USE SURFACE LOADING RATES, CONSTITUENT/TSS, mg/g

Constitutent	Land Use Grazing and Open	 Ag-Orchard/ Vineyard	 Ag-Truck/ Field/Crops
Settleable Solids	(600)*	(600)	(600)
BOD_5	3.2	3.2	3.2
Suspended Solids	1,000	1,000	1,000
Fecal Coliforms**	(28,000)	(11,000)	(11,000)
Oil and Grease	2.2	2.2	2.2
Total Nitrogen	2.6	2.6	2.6
Phosphorus	0.2	0.2	0.2
Total Heavy Metals	0.3	0.3	0.3

* (   ) Ratio adopted from WRE's Iowa work.
** Fecal coliforms per gram SS.

MODEL CALIBRATION

Very little data was available for calibrating either the Runoff-Quality Model or QUAL-II. A few streamflow measurements in the Laguna and Petaluma Basins were used to calibrate the Runoff portion of the Runoff-Quality Model. There is no historical wet weather quality data against which to compare the quality simulations. Consequently, wet weather quality results are based on coefficients that were developed for three different areas. Urban surface loading rates come from the storm drainage work performed by WRE in Seattle, certain of the rural loading coefficients and other coefficients were developed from data presented in the Basin Plan for Sonoma County. Dry weather data for calibration consisted of several grab samples taken during the summer of 1973 at several stations along the Laguna de Santa Rosa and a few samples taken in the vicinity of the old Petaluma STP on the Petaluma River.

Calibration of Runoff-Quality Model

The only streamflow records appropriate for calibration purposes are those published by the U.S. Geological Survey in the annual "Water Resources Data for California, Surface Water Records." These are:

Stream	Drainage Area (sq. kilometers)	Period of Record
Petaluma River at Petaluma	80.3	1948-1963
Mark West Creek at Windsor	111.4	1940-1941
Santa Rosa Creek near Santa Rosa	33.7	1959-1970

The U.S. Geological Survey has a gage on Laguna de Santa Rosa near Graten, but is of no value in calibration because only water levels are measured and these levels are directly affected by flow conditions in the Russian River.

The calibration process was confined entirely to quantity of runoff, as there is no available water quality data for individual storm events.

Results from applications of the model in other locations have shown that the percent impervious and the maximum and minimum infiltration rates are the only parameters to be determined in the runoff quantity calibration process. All other parameters have been found to be relatively standard for several locations in the United States.

The standard values for Manning's coefficient of roughness are 0.013 for impervious surfaces and 0.250 for pervious surfaces. The surface storage detention depth is 1.6 mm (1/16-inch) for impervious surfaces and 4.8 mm (3/16-inch) for pervious surfaces.

In calibrating the model, it is necessary to have a specific rainfall hyetograph and the resulting streamflow hydrograph. After reviewing the available data it was found that there were rainfall and runoff measurements for only a few medium to heavy storms. Low intensity storms are inappropriate for calibration because anticedent moisture, high base flows, and other conditions can greatly modify the runoff process. Therefore, the calibration work had to be confined to these few medium to heavy storms.

The first step was to select a specific storm event, use the rainfall hyetograph for that storm to drive the model, and then compare the simulated streamflow hydrograph with the gaged hydrograph. This was done for the Petaluma Basin and the initial simulation results were lower than the gaged flows. The impervious percentages in uplands and hill areas were then increased to reflect the rock outcrops and shallow soil depth over bedrock as reported in the 1972 Soil Survey of the U.S. Department of Agriculture (4). In addition, the infiltration rates were decreased from those reported by the USDA Soil Survey for agricultural lands to lower values used by the Crops of Engineers in their "Survey Report for Flood Control and Allied Purposes, Petaluma River Basin", of 1972 (7).

With these above described changes, subsequent simulations were made which result in increased runoff. Figures F-2 and F-3 show the simulated and gaged hyrdographs for two storms in December 1955, both of which represent flows resulting from rain storms having approximately 10 to 20 year recurrence intervals.

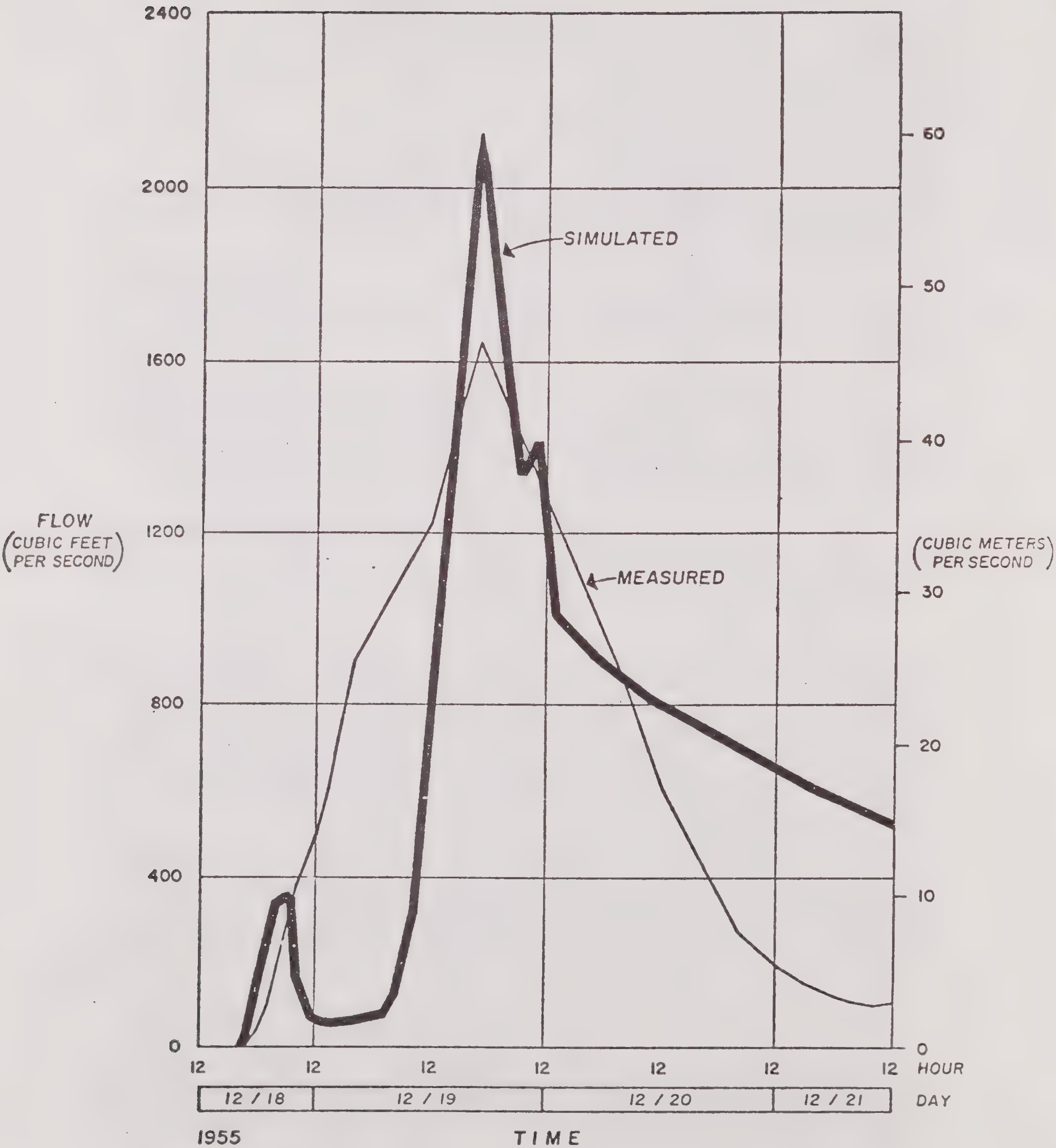


Figure F-2

MEASURED FLOWS VERSUS MODEL SIMULATIONS
December 18-21, 1955

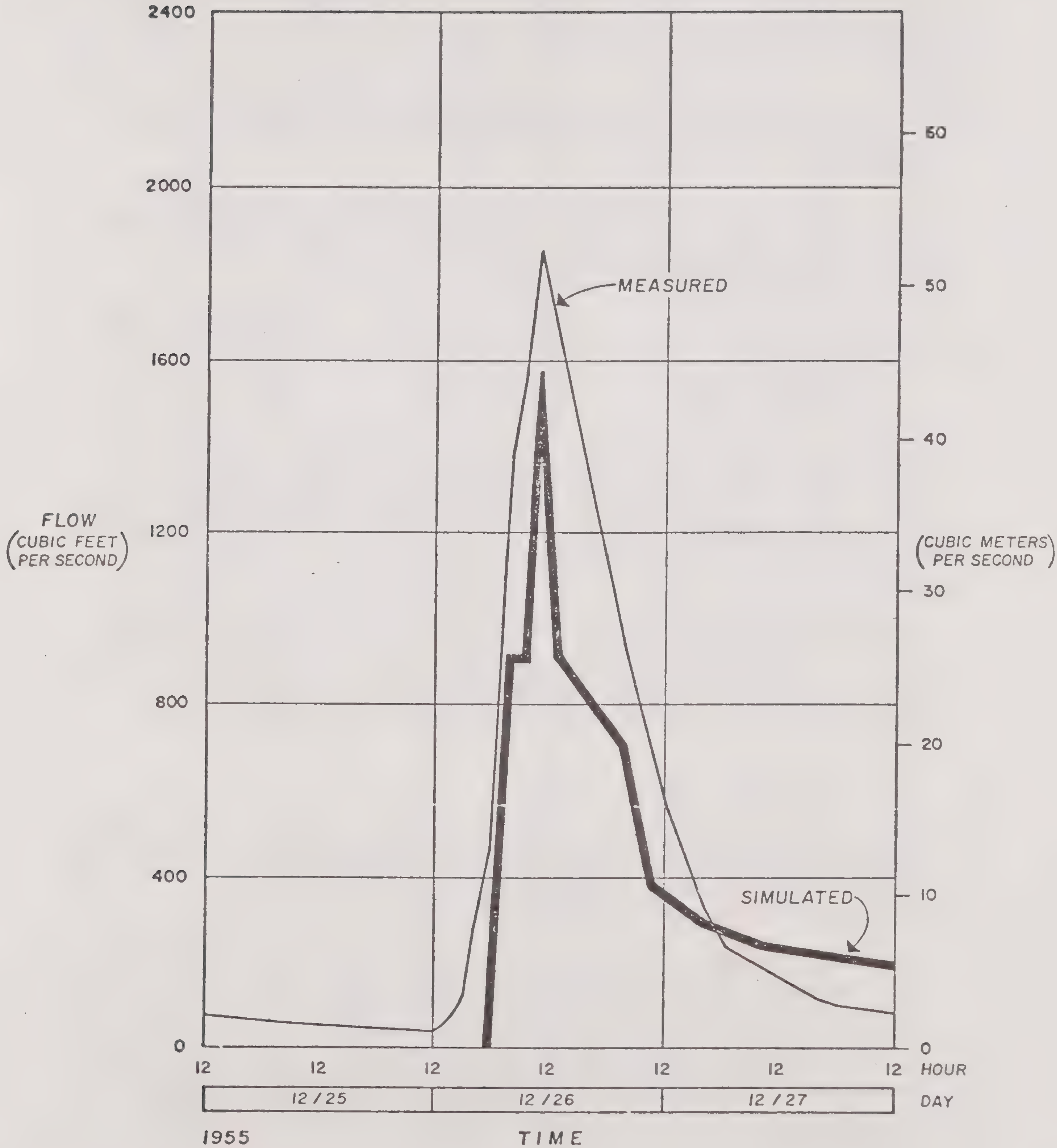


Figure F-3

MEASURED FLOW VERSUS MODEL SIMULATION
December 25-27, 1955

These simulations are based on rain storms applied uniformly over the entire Petaluma Basin when, in fact, there are variations in time and in rainfall amounts as the storm moves across the Basin. Therefore, more refined calibration cannot be made without additional rainfall data.

The adjusted parameters from the Petaluma Basin were then applied to the Laguna Basin. A specific storm was selected and applied to the Laguna Basin.

The results of this initial Laguna Basin simulation, and a second simulation, yielded good results. However, only peak flow rates were compared to gaged values as hydrographs were not available for Santa Rosa Creek. The results are as follows:

Date of Storm	Gaged Peak Flow	Simulated Peak Flow
December 22, 19764	52.4 m^3/sec	50.4 m^3/sec
January 21, 1970	60.2 m^3/sec	64.4 m^3/sec

In addition, a rough comparison of peak flows was made for Mark West Creek near Windsor. Based upon limited U.S.G.S. gaging records, and Sonoma County Water Agency estimates, the peak flow from a storm event having a five-year recurrence interval should be roughly 224 to 252 m^3/sec. The peak flow simulated by the model for a five-year storm was 207 m^3/sec.

The Runoff-Quality Model calibration process was adequately completed for use in this study, but it was not an extensive techical research effort. The results indicate adequate to good representation of both the Petaluma and Laguna Basins, and the user can be confident that the calibrated model reasonably represents the runoff process.

Calibration of the QUAL-II Model

Laguna de Santa Rosa - Comparisons of computed quality results with field data measured during the summer of 1973 are shown in Figures F-4 and 9. The differences exhibited reflect a number of things about the model, the Laguna itself, and the measured data.

First, an overview of all the results indicates that algal activity was phenomenal in the Laguna near Occidental Road, just downstream of the Sebastopol waste treatment plant and upstream of Santa Rosa Creek. The algal numbers were very high (5900/ml maximum); the nutrients, NO_3 and PO_4, were being depleted by the growing algae; NH_3 was being converted to nitrate or used directly by algae; and the photosynthetic process was producing dissolved oxygen at a rate that resulted in concentrations as high as 24 mg/1, a significant degree of super-saturation.

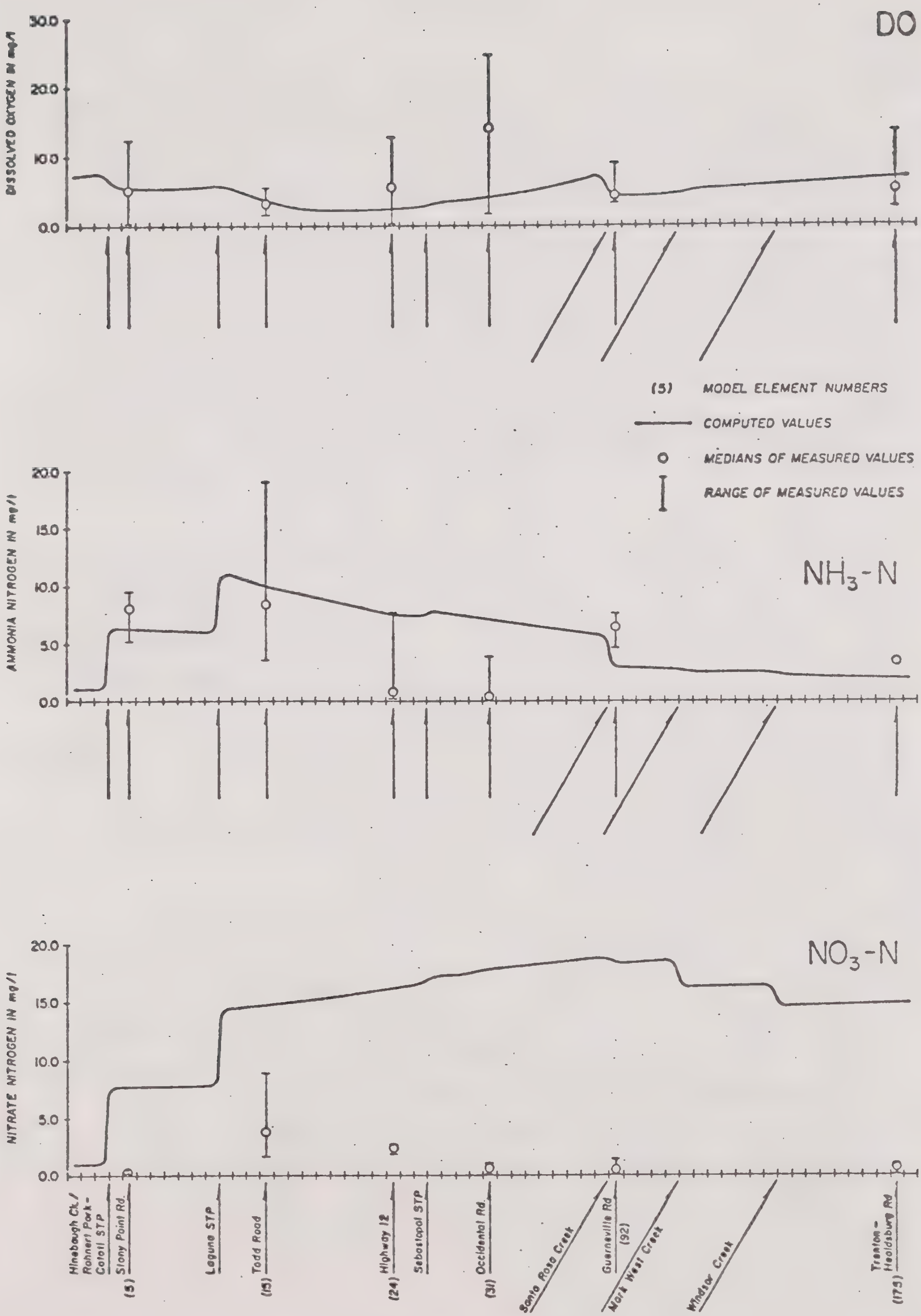


Figure F-4

MEASURED AND MODELED QUALITY PROFILES
FOR THE LAGUNA DE SANTA ROSA

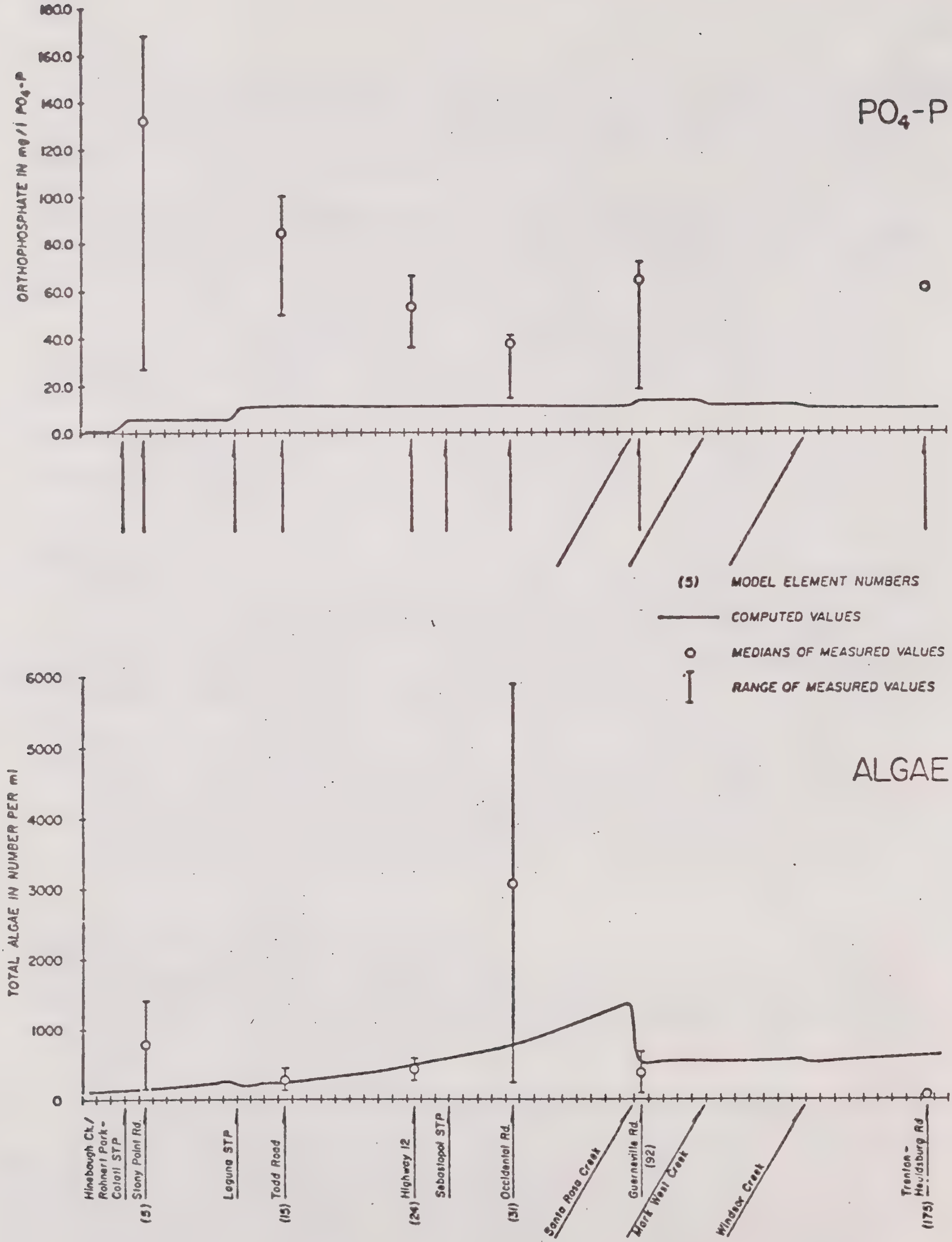


Figure F-5

MEASURED AND MODELED QUALITY PROFILES
FOR THE LAGUNA DE SANTA ROSA

Several differences between the measured and modeled profiles are worth noting. First the measured nitrate nitrogen and phosphate phosphorus concentration were quite different from the modeled concentrations. The measured nitrate values were much lower and the phosphate values were much higher than those modeled. The concentrations of nitrate assumed for the headwaters and waste treatment plants were actually not unreasonable (1-20 mg/1). The measured values of phosphate at 50 to 150 mg/1 are inextricably high. One has to wonder if these measurements were not made from unfiltered samples containing insoluble phosphate, particularly since the reported PO_4-P values were sometimes higher than total dissolved solids concentrations measured at the same time. In one respect it is not terribly significant that the reported values and the modeled values for the two nutrients were always higher than the "half saturation constants" for NO_3 (0.3 mg/1) and PO_4 (0.03 mg/1), which means that neither nutrient was limiting to the algal growth that occurred, either in the model or in the Laguna.

An interesting feature of the model's results is the continuity of the profiles produced; which by contrast with the measurements taken at sparse and discrete points in the field, gives a truer, more informative picture of how each plant discharge and tributary inflow affects the concentrations downstream. An especially notable example is the impression given by the algae data that a peak bloom occurred near Occidental Road and somehow disappeared by the time the water reached Guerneville Road downstream. The model probably more accurately reflects that the algae continued to grow downstream of Occidental Road, but they were then drastically diluted by the inflow of water from Santa Rosa Creek which occurs just slightly upstream of where the next measurement was made, at Guerneville Road. In other words, the model and the data measured in the field are best utilized when they are used together to ascertain both the form and the degree of behavior.

Finally it should be made clear that WRE did not model algal numbers but indeed algal mass. Algal mass was in turn reflected as mass of chlorophyll-A which was assumed to be one-twentieth of the algal cell's mass. The conversion to algal numbers per ml was made merely to compare the modeled results with what was measured in the field. The relevant data for the conversion were a 0.025 mm diameter of a spherical algal cell, a specific gravity of the algae of 1.05, and 1 mg of algae per 50 μg of Chl-A.

The results for algae and dissolved oxygen which are the constituents most reflective of the final effect of what occurs, indicate that the model was reasonably well calibrated, if not a perfect representation of prototype behavior. The data are fraught with inaccuracies as well, of course; but again the two together give an explainable picture of how the Laguna behaves during dry weather. This was the point of the exercise.

Petaluma River - Quality data available for calibration of BOD, DO, and other model parameters were measured by the City near the old Petaluma waste treatment plant. The results from the model compared favorably with the measured data at this one point, but the measurements were not areally extensive enough to permit comparisons of profiles.

As described in Chapter III, the model was calibrated with total dissolved solids concentrations measured by the Regional Board.

REFERENCES

1. U. S. Army Corps of Engineers, Seattle District, "Appendix B, Urban Storm Drainage Simulation Models", Environmental Management for the Metropolitan Area Cedar-Green River Basins, Washington, December 1974.

2. Water Resources Engineers, Inc., Agricultural Watershed Runoff Model for the Iowa-Cedar River Basins, November 1975.

3. Water Resources Engineers, Inc., Computer Program Documentation for the Stream Quality Model QUAL-II, August 1974.

4. U. S. Department of Agriculture, "Soil Survey, Sonoma County, California", May 1972.

5. Huber, Wayne C., et al., Storm Water Management Model Interim Revised Users' Manual, National Environmental Research Center, Office of Research and Development, U. S. Environmental Protection Agency, Cincinnati, Ohio, August 1974 (Draft Report).

6. California State Water Resources Control Board, Water Quality Control Plan, San Francisco Bay Basin (2), April 1975.

7. Corps of Engineers, "Survey Report for Flood Control and Allied Purposes, Petaluma River Basin", 1972.

BIBLIOGRAPHY

BIBLIOGRAPHY

BOOKS

Berry, Brian J. L., et. al., Land Use, Urban Form, and Environmental Quality, Chicago, Ill.: University of Chicago, 1974.

Berry, Brian J. L. and Frank Horton, Urban Environmental Management, Planning for Pollution Control, Englewood Cliffs, N.J.: Prentice Hall, 1974.

Bosselman, Fred P., Duane A. Feurer and David L. Callies, EPA Authority Affecting Land Use, Chicago, Ill.: Ross, Hardies, O'Keepe, Babcock, and Parsons, March, 1974.

Bower, Blair T. and Daniel J. Basta, Residuals-Environmental Quality Management: Applying the Concept, Baltimore, Md.: Johns Hopkins Center For Metropolitan Planning and Research, 1973.

Chapin, F. Stuart, Jr.; Weiss, Shirley F. (Editors), Urban Growth Dynamics in a Regional Cluster of Cities, New York: Wiley, 1962.

Carey, George W., Leonard Zobler, Michael Greenberg and Robert Horden, Urbanization, Water Pollution, and Public Policy, New Brunswick, N.J.: Center for Urban Policy Research, Rutgers University, 1972.

Grava, Sigurd, Urban Planning Aspects of Water Pollution Control, New York, N.Y.: Columbia University Press, 1969.

Hagevik, George (ed.), The Relationship of Land Use and Transportation Planning to Air Quality Management, New Brunswick, N.J.: Center for Urban Policy Research, Rutgers University, 1972.

Hagevik, George, Daniel Mandelker and Richard Brail, The Contribution of Urban Planning to Air Quality, Research Triangle Park, N.C.: U.S. Environmental Protection Agency, 1974.

Harbridge House, Inc., Key Land Use Issues Facing EPA, Washington, D.C.: U.S. Environmental Protection Agency, February, 1974.

Kneese, Allen V., Robert U. Ayres and Ralph C. d'Arge, Economics and the Environment: A Materials Balance Approach, Baltimore, Md.: Johns Hopkins Press, 1970.

Kneese, Allen V. and Blair T. Bower, Environmental Quality Analysis, Baltimore, Md.: Johns Hopkins Press, 1972.

Kneese, Allen V., et. al., Managing the Environment, New York, N.Y.: Praeger Publishers, Inc., 1971.

Kneese, Allen V. and Blair T. Bower, Managing Water Quality: Economics, Technology Institutions, Baltimore Md.: Johns Hopkins Press, 1968.

McAllister, Donald M. (ed.), Environment: A New Focus for Land Use Planning, Washington, D.C.: National Science Foundation, Research Applied to National Needs, 1973.

Milgram, Grace, The City Expands, Philadelphia, Pa.: University of Pennsylvania, Institute of Environmental Studies, 1967.

Mylroie, Gerald R. and Karen Towne, California Environmental Law: A Guide, Claremont, Calif.: Center for California Public Affairs, 1974.

Raven-Hansen, Peter, et al., Water and the Cities: Contemporary Urban Water Resource and Related Land Planning, Cambridge, Mass.: ABT. Associates, Inc., 1969.

Real Estate Research Corporation, The Costs of Sprawl, Washington, D.C.: Real Estate Research Corp., April, 1974.

Salama, Ovadia A., Planning and Human Values: An Inquiry Into the Phenomenon of Urban Growth and the Possibility of its Control Through Water and Land Related Actions, Cambridge, Mass.: ABT. Associates, 1974.

Schneider, Jerry B. and Joseph R. Beck, Reducing the Travel Requirements of the American City: An Investigation of Alternative Urban Spatial Structures, Seattle, Wash.: Urban Transportation Program, University of Washington, 1973.

Sedway/Cooke Urban and Environmental Planners and Designers, Land and the Environment; Planning in California Today, Los Altos, Calif.: William Kaufman, Inc., 1975.

Werczberger, Elia, Locational Aspects of Air Quality Policies, Ithaca, N.Y.: Center for Urban Development Research, Cornell University, 1974.

ARTICLES

Bower, Blair T., "Residuals and Environmental Management," Journal of the American Institute of Planners, Vol. 37 (No. 4, July, 1971), p. 218.

Calder, K. L., "Mathematical Modeling of Air Quality Through Calculation of Atmospheric Transport and Diffusion," Proceedings of the Third Meeting of the Expert Panel on Air Pollution Modeling, Paris, France, CCMS/NATO, October 2-3, 1972.

Chapin, F. Stuart and Shirley F. Weiss, "Land Development Patterns and Growth Alternatives," Urban Growth Dynamics In A Regional Cluster of Cities, New York, N.Y.: Wiley, 1962.

Everett, Michael D., "Roadside Air Pollution In Recreational Land Use Planning," Journal of the American Institute of Planners, Vol. 40 (March, 1974), p. 83.

Gifford, F. A., Jr. and Steven R. Hanna, "Urban Air Pollution Modeling," Proceedings of 2nd International Clean Air Congress, New York, N.Y.: Academic Press, 1971, p. 1146.

Articles (cont'd)

Hanna, Steven R., "A Simple Method of Calculating Dispersion From Urban Area Sources," Journal of Air Pollution Control Association, Vol. 21 (1971), p. 774.

Hanna, Steven R., "Application of A Simple Model of Photochemical Smog," Proceedings of the 3rd Clean Air Congress of the International Union of Air Pollution Prevention Association, Dusseldorf, Germany, October 8-12, 1973.

King, Kathleen, "Federal Land Use Controls for Clean Air," Environmental Affairs, Vol. 3 (No. 3, 1974) p. 503.

Kurtzweg, Jerry A., "Urban Planning and Air Pollution Control: A Review of Selected Recent Research," Journal of the American Institute of Planners, Vol. 39 (No. 2, March, 1973) p. 82.

Mandelker, Daniel R. and Susan B. Rothschild, "The Role of Land Use Controls in Combating Air Pollution Under the Clean Air Act of 1970," Ecology Law Quarterly, Vol. 3 (No. 2, Spring, 1973) p. 235.

Ridker, Ronald G. and John A. Henning, "The Determinants of Residential Property Values, with Special Reference to Air Pollution," The Review of Economics and Statistics, Vol. XLIX (May, 1967), p. 246.

Rydell, C. Peter and Benjamin H. Stevens, "Air Pollution and the Shape of Urban Regions," Journal of the American Institute of Planners, Vol. 34 (No. 1, January, 1968) p. 50.

Simmons, William and Robert H. Cutting, Jr., "A Many Layered Wonder: Nonvehicular Air Pollution Control Law in California," reprinted from The Hastings Law Journal, Vol. 26 (No. 1, September, 1974).

Steinfield, John H. and Wen H. Chen, "Optimal Distribution of Air Pollution Sources," Atmospheric Environment, Vol. 7 (No. 11, January, 1973) p. 87.

Wenner, Lettie McSpadden, "Federal Water Pollution Control Statutes in Theory and Practice," Environmental Law, Vol. 4 (No. 2, Winter, 1974) p. 251.

REPORTS

American Public Works Association, Water Pollution Aspects of Urban Runoff, Washington, D.C.: United States Federal Water Pollution Control Administration, 1969.

Argonne National Laboratory, Center for Environmental Studies, Air Pollution/Land Use Planning Project, Phase II, Final Report, Vol. II, Argonne, Ill.: May, 1973.

Argonne National Laboratory, Energy and Environmental Studies Division, and American Society of Planning Officials, Interagency Cooperation in Comprehensive Urban Planning and Air Quality Maintenance, Argonne, Ill.: March, 1974.

Association of Bay Area Governments - Metropolitan Transportation Commission, Projections of the Regions Future Growth, Series 2, Berkeley, Calif.: Association of Bay Area Governments, September, 1974.

AVCO Economic Systems Corporation, Storm Water Pollution From Urban Land Activity, Washington, D.C., 1970.

Bascom, S. E., et. al., Secondary Impacts of Transportation and Wastewater Investments: Review and Bibliography, Washington, D.C.: U.S. Environmental Protection Agency, January, 1975.

Bay Area Air Pollution Control District, "A Study to Assess the Impact of Growth upon the Air Quality of Southeastern Marin County," San Francisco, Calif.: 1972.

Bay Area Air Pollution Control District, Air Quality and Growth in Marin County, San Francisco, Calif.: June, 1972.

Bay Area Sewage Services Agency, Regional Water Quality Management Plan, Berkeley, Calif.: 1973.

Bay Area Sewage Services Agency, The Bay Area Sewage Services Agency Act, (including 1972 Amendments), Berkeley, Calif.: April, 1973.

Becker, Burton C., et. al., Approaches to Stormwater Management, Columbia, Md.: Hittman Associates, Inc., November, 1973.

Benell, Ruth, A Guide to Procedures for City Incorporations, Annexations and Minor Boundary Changes; Special District Principal Acts; District Reorganization Act, Los Angeles, Calif.: Los Angeles County Local Agency Formation Commission, 1974.

Branch, Melville C. and Eugene Leong, (eds.), Research Investigation, Air Pollution, and City Planning, Case Study of A Los Angeles District Plan, Los Angeles, Calif.: Environmental Science and Engineering, University of California, 1972.

Busse, Adrian D. and John R. Zimmerman, User's Guide to the Climatological Dispersion Model, Washington, D.C.: U.S. Environmental Protection Agency, Environmental Monitoring Series, December, 1973.

California Air Resources Board, Air Quality - Land Use Planning Handbooks for California - Part I; Planning for Air Quality, Sacramento, Calif.: April, 1975.

Reports (cont'd)

California Air Resources Board, Summary Report on Current Methodologies for Determining the Spatial Distribution of Air Polluting Emissions, Sacramento, Calif.: July, 1974.

California Air Resources Board, The Air Quality Land Use Planning Process in California: Status June, 1974, unpublished, Sacramento, Calif.: July, 1974.

California State Water Resources Control Board, Regional Water Quality Control Board, North Coast Region (1), Water Quality Control Report, Part I, August, 1974.

California State Water Resources Control Board, Regional Water Quality Control Board, San Francisco Bay Region (2), Tentative Water Quality Control Report, Part II, November, 1974.

Colston, Newton, Charterization and Treatment of Urban Land Runoff, Cincinnati, Ohio: U.S. Environmental Protection Agency, National Environmental Research Center, 1974.

Coughlin, Robert E. and Thomas R. Hammer, Stream Quality Preservation through Planned Urban Development, Washington, D.C.: U.S. Environmental Protection Agency, Office of Research and Development, May, 1973.

Council on Environmental Quality, Environmental Quality; The Fourth Annual Report of the Council on Environmental Quality, Washington, D.C.: U.S. Government Printing Office, 1973.

Council on Environmental Quality, Environmental Quality; The Fifth Annual Report of the Council on Environmental Quality, Washington, D.C.: U.S. Government Printing Office, 1974.

Crawford, N. H. and R. K. Linsley, Digital Simulation in Hydrology: Stanford Watershed Model IV, Palo Alto, Calif.: Stanford University, Department of Civil Engineering, Technical Report No. 39, July, 1966.

Croke, E. J., K. G. Croke and Allen S. Kennedy, The Impact of Urban Growth and Development on The Achievement of Air Quality Standards, Argonne, Ill.: Argonne National Laboratory, 1971.

Dabberdt, Walter F. and Richard Sandys, Assessment of the Air Quality Impact of Indirect Sources, Menlo Park, Calif.: Stanford Research Institute, 1974.

Dabberdt, Walter F., Richard C. Sandys and Patricia A. Buder, A Population Exposure Index for Assessment of Air Quality Impact, Menlo Park, Calif.: Stanford Research Institute, 1974.

deLeon, Peter and John Enns, The Impact of Highways Upon Metropolitan Dispersion: St. Louis, Santa Monica, Calif.: The Rand Corporation, September, 1973.

Engineering Science, Inc. and Howard, Needles, Tammen and Bergdorf, Development of a Trial Air Quality Maintenance Plan Using the Baltimore Air Quality Control Region, Research Triangle Park, N.C.: U.S. Environmental Protection Agency, Office of Air and Waste Management, Office of Air Quality Planning and Standards, September, 1974.

Environmental Research and Technology, Inc., A Guide for Considering Air Quality in Urban Planning, Lexington, Mass.: March, 1974.

Environmental Research and Technology, Inc., The Hackensack Meadowlands Air Pollution Study, Lexington, Mass.: October, 1973.

Eschenroeder, A. Q. and J. R. Martinez, Further Development of the Photochemical Smog Model for the Los Angeles Basin, Los Angeles, Calif.: General Research Corporation, March, 1971.

GCA Corporation and TRW, Inc., Transportation Controls to Reduce Motor Vehicle Emissions in Major Metropolitan Areas, Washington, D.C.: U.S. Environmental Protection Agency, Office of Air and Water Programs, December, 1972.

General Electric Company, Final Report on Study of Air Pollution Aspects of Various Roadway Configurations, Philadelphia, Pa.: General Electric Co., 1971.

Goeller, F. Bruce, et. al., San Diego Clean Air Project: Summary Report, Santa Monica, Calif.: The Rand Corporation, December, 1973.

Horowitz, Joel and Steven Kuhrtz, Transportation Controls to Reduce Automobile Use and Improve Air Quality in Cities; the Need, the Options, and Effects on Urban Activity, Washington, D.C.: U.S. Environmental Protection Agency, November, 1974.

Hufschmidt, Maynard, Water Resource Planning in the Urban - Metropolitan Context, Chapel Hill, N.C.: Report to the U.S. Office of Water Resources, 1971.

Hydrocomp International, Hydrocomp Simulation Programming - Operations Manual, Palo Alto, Calif.: February, 1972.

Institute of Public Administration and Teknekron, Inc., in cooperation with TRW, Inc., Evaluating Transportation Controls to Reduce Motor Vehicle Emissions in Major Metropolitan Areas, Prepared For U.S. Environmental Protection Agency, 1972.

Kaiser, Edward J., et. al., Promoting Environmental Quality Through Urban Planning and Controls, Washington, D.C.: Superintendent of Documents, 1974.

Reports (cont'd)

Kennedy, Alan S. et. al., Air Pollution - Land Use Planning Project, Argonne, Ill.: Argonne National Laboratory, Center for Environmental Studies, Vol. I: Selected Land Use Control Policies for Air Quality Management, May, 1973. Vol. II: Methods for Predicting Air Pollution Concentrations from Land Use, May, 1973. Vol. III: An Economic Comparison of Point-Source Controls and Emission Density Zoning for Air Quality Management, May, 1973.

Knox, J. B., et. al., Development of an Air Pollution Model for the San Francisco Bay Area, Second Semiannual Report, Livermore, Calif.: Lawrence Livermore Laboratory, February, 1974.

Lager, John A. and William G. Smith, Urban Stormwater Management and Technology: An Assessment, Washington, D.C.: U.S. Government Printing Office, December, 1974.

Land Use Subcommittee of the Advisory Committee to the Department of Housing and Urban Development, Urban Growth and Land Development; The Land Conversion Process, Washington, D.C.: National Academy of Sciences, National Academy of Engineering, 1972.

Larsen, R. I., A Mathematical Model for Relating Air Quality Measurements to Air Quality Standards, AP-89, Research Triangle Park, N.C.: U.S. Environmental Protection Agency, November, 1971.

Leclerc, Guy and John C. Shaake, Jr., Methodology for Assessing the Potential Impact of Urban Development on Urban Runoff and the Relative Efficiency of Runoff Control Alternatives, Cambridge, Mass.: Massachusetts Institute of Technology., March, 1973.

Legates, Richard, T., California Local Agency Formation Commissions, Berkeley, Calif.: Institute of Governmental Studies, 1970.

Livingston and Blayney, A Report on Guidelines for Relating Air Pollution Control to Land Use and Transportation Planning in the State of California, Sacramento, Calif.: California State Air Resources Board, 1973.

McPherson, M. B., et. al., Management of Urban Storm Runoff, New York, N.Y.: American Society of Civil Engineers, May, 1974.

Mallory, Charles W., The Beneficial Uses of Storm Water, Washington, D.C.: Government Printing Office, 1973.

Marcuso, R. L. and F. L. Ludwig, User's Manual for the APRAC-IA Urban Diffusion Model Computer Program, Menlo Park, Calif.: Stanford Research Institute, January, 1969.

Martinez, J. R., User's Guide to Diffusion/Kinetics (DIFKIN) Code, Washington, D.C.: U.S. Environmental Protection Agency, Environmental Monitoring Series, October, 1972.

Metcalf and Eddy, Inc., University of Florida and Water Resources Engineers, Inc., Stormwater Management Model, Washington, D.C.: U.S. Environmental Protection Agency, October, 1971.

Metropolitan Transportation Commission, Regional Transportation Plan for the San Francisco Bay Area, Berkeley, Calif.: August, 1974.

Meyer, Charles F., Polluted Groundwater: Some Causes, Effects, Controls and Monitoring, Washington, D.C.: U.S. Environmental Protection Agency, Office of Research and Development, 1973.

Northeastern Illinois Planning Commission, Managing the Air Resource in Northern Illinois, Technical Report No. 6, Chicago, Ill.: 1967.

PEDCo Environmental Specialists and Vogt, Sage, and Pflum, Air Pollution Considerations in Residential Planning; Vol. I: Manual, Vol. II: Backup Report, Research Triangle Park, N.C.: U.S. Environmental Protection Agency, July, 1974.

Pines, David, "Urban Growth, Air Pollution, and the Demand for Housing in the Center of the City," Working Paper No.6, Tel Aviv: Tel Aviv University, 1971.

Poertner, Herbert G., Practices in Detention of Urban Stormwater Runoff, Chicago, Ill.: American Public Works Association, 1974.

Promise, J. and M. Leiserson, Water Resources Management for Metropolitan Washington: Analysis of the Joint Interactions of Water and Sewage Service, Public Policy, and Land Development Patterns in An Expanding Metropolitan Area, Washington, D.C.: Metropolitan Washington Council of Governments, December, 1973.

Roddin, Marc, et. al., An Analysis of the Proposed Parking Management Regultions of the Environmental Protection Agency, Menlo Park, Calif.: Stanford Research Institute, 1974.

Rivkin/Carson, Inc., The Sewer Moratorium as A Technique of Growth Control and Environmental Protection, Washington, D.C.: U.S. Department of Housing and Urban Development, June, 1973.

San Bernardino Environmental Improvement Agency, The Air Quality Plan of San Bernardino County, San Bernardino, Calif.: October, 1975.

San Diego Comprehensive Planning Organization, Water, Wastewater and Flood Control Facilities Planning Model, Technical Report, San Diego, Calif.: January, 1974.

Sartor, James D. and Gail B. Boyd, Water Pollution Aspects of Street Surface Contaminants, Washington, D.C.: U.S. Environmental Protection Agency, Office of Research and Monitoring, November, 1972.

Reports (cont'd)

Sedway/Cooke Urban and Environmental Planners and Designers, "Guide to Implementation Techniques for Air and Water Quality Management Plans," Prepared for Association of Bay Area Governments, Berkeley, Calif.: January, 1976.

Shaheen, Donald G., Contributions of Urban Roadway Usage to Water Pollution, Washington, D.C.: U.S. Environmental Protection Agency, Office of Research and Development, April, 1975.

State of California, Department of General Services, Documents Division, Laws Relating to Conservation and Planning, Sacramento, Calif.: 1972.

Stone, Ralph and Herbert Smallwood, Intermedia Aspects of Air and Water Pollution Control, Washington, D.C.: Government Printing Office, 1973.

Strong, Ann L. and John C. Keene, Environmental Protection Through Public and Private Development Controls, Washington, D.C.: Suptintendent of Documents, 1973.

Texas Water Development Board, QUAL - I - Simulation of Water Quality in Streams and Canals - Program Documentation and User's Manual, Austin, Texas: September, 1970.

Thuillier, Richard H., A Regional Air Pollution Modeling System for Practical Application in Land Use Planning Studies, San Francisco, Calif.: Bay Area Air Pollution Control District, May, 1973.

Thuillier, Richard H., Air Quality Statistics in Land Use Planning Applications, Third Conference on Probability and Statistics in Atmospheric Science, Boulder, Colorado, June, 1973.

Thurow, Charles, William Toner and Duncan Erley, Performance Controls for Sensitive Lands: A Practical Guide for Local Administrators, Washington, D.C.: U.S. Environmental Protection Agency, March, 1975.

Tourbier, Joachim, Water Resources as A Basis for Comprehensive Planning and Development of the Christina River Basin, Newark, Delaware: Water Resources Center, University of Delaware, 1973.

Tourbier, Joachim and Richard Westmacott, Water Resources Protection Measures in Land Development - A Handbook, Newark, Delaware: Water Resources Center, University of Delaware, April, 1974.

TRW Inc., Air Quality Management Plan and Program Recommendations Middlesex County, New Jersey, McLean, Va.: TRW, Inc., 1974.

TRW Inc., Development of A Sample Air Quality Maintenance Plan for San Diego, Research Triangle Park, N.C.: U.S. Environmental Protection Agency, September, 1974.

TRW, Inc., Prediction of the Effects of Transportation Controls on Air Quality in Major Metropolitan Areas, Prepared for U.S. Environmental Protection Agency, November, 1972.

TRW Systems Group, Air Quality Display Model, Washington, D.C.: National Air Pollution Control Administration, 1969.

TRW, Inc., Transportation and Environmental Operations, Air Quality Implementation Plan Development for Critical California Regions: San Francisco Bay Intrastate Air Quality Control Region, August, 1973.

University of Delaware, Water Resources Center, The Christina Basin: The Protection of Water Resources as A Basis for Planning in Developing Areas, Newark, Delaware: Delaware University, 1972.

Urban Systems Research and Engineering, Inc., Interceptor Sewers and Suburban Sprawl: The Impacts of Construction Grants on Residential Land Use, Cambridge, Mass.: 1974.

URS Research Company, Water Quality Management Planning for Urban Runoff, San Mateo, Calif.: December, 1974.

U.S. Corps of Engineers, Hydrologic Engineering Center, "Urban Storm Water Runoff: STORM," Computer Program 723-S8-L2520, January, 1975.

U. S. Department of the Interior, Federal Water Quality Control Administration, Storm Water Pollution from Urban Land Activity, Washington, D.C.: U.S. Department of the Interior, FWQC Administration, July, 1970.

U. S. Environmental Protection Agency, Guidelines for Air Quality Maintenance Planning and Analysis - Volume 3: Control Strategies, Research Triangle Park, N.C.: July, 1974.

U. S. Environmental Protection Agency, Guidelines for Air Quality Maintenance Planning and Analysis, Vol. 13: Allocating Projected Emissions to Subcounty Areas, Washington, D.C. November, 1974.

U. S. Environmental Protection Agency, Water Quality Management Planning for Urban Runoff, Washington, D.C., 1974.

U. S. Environmental Protection Agency, Office of Air and Water Programs, Methods for Identifying and Evaluating the Nature and Extent of Nonpoint Sources of Pollution, Washington: U.S. Govt. Printing Office, 1973.

U. S. Environmental Protection Agency, Office of Air and Water Programs, Processes, Procedures, and Methods to Control Pollution Resulting from All Construction Activity, Washington, D.C., October, 1973.

Reports (cont'd)

U. S. Environmental Protection Agency, Office of Water Planning and Standards, Water Quality Management Planning for Urban Runoff, Washington, D.C., 1974.

U. S. Environmental Protection Agency, Water Planning Division, Urban Stormwater Management Research and Planning Projects for FY 1975 and FY 1976, Information package, Washington, D.C., March, 1975.

U. S. Environmental Protection Agency, Water Planning Division, Areawide Management Branch, "Annotated Bibliography for Areawide Water Quality Management," Washington, D.C., 1975.

U. S. Water Resources Council, Water and Related Land Resources; Establishment of Principles and Standards for Planning, Washington, D.C.: National Archives, 1973.

U. S. Water Resources Scientific Information Center, Urbanization and Sedimentation; A Bibliography, Washington, D.C.: The Center, 1971.

Alan M. Voorhees and Associates, Inc., Baltimore Regional Environmental Impact Study (BREIS), March, 1974.

Alan M. Voorhees and Associates, Guidelines for Air Quality Maintenance and Analysis; Volume 4: Land Use and Transportation Considerations, Research Triangle Park, N.C.: U. S. Environmental Protection Agency August, 1974.

Alan M. Voorhees and Associates, Guidelines to Reduce Energy Consumption Through Transportation Actions, Washington, D.C.: Urban Mass Transit Administration, May, 1974.

Alan M. Voorhees and Associates, In Association with Herman D. Ruth and Associates, An Assessment of Secondary Air Quality Impacts and Potential Mitigation Measures for A Wastewater Treatment Facility in Central Contra Costa County - Interim Progress Report, June 4, 1975.

Alan M. Voorhees and Associates; Ryckman, Edgerly and Tomlinson and Associates, A Guide for Reducing Air Pollution Through Urban Planning, Research Triangle Park, N.C.: U. S. Environmental Protection Agency, December, 1971.

Alan M. Voorhees and Associates, Water Resources Engineers, Inc., and Environments for Tomorrow, Inter-Relationships of Land Use Planning and Control to Water Quality Management Planning, Washington, D.C.: U. S. Environmental Protection Agency, April, 1973.

Water Resources Engineers, Application of the EPA Stormwater Management Model to Agricultural Watersheds for the Iowa - Cedar River Basins, Washington, D.C.: U. S. Environmental Protection Agency, Systems Development Branch, 1973.

80 09654

Reports (cont'd)

Water Resources Engineers, Computer Program Documentation for the Stream Quality Model QUAL II, Washington, D.C.: U. S. Environmental Protection Agency, October, 1973.

Welson, John R. and Benjamin H. Stevens, Air Quality and Its Relationship to Economic, Meteorological, and Other Structural Characteristics of Urban Areas in the United States, RSRI Discussion Series Paper, Series No. 42, Philadelphia, Pa.: Regional Science Research Institute, 1970.

Williams, J. D., et. al., Air Pollutant Emissions Related to Land Area - A Basis for A Preventative Air Pollution Control Program, Durham, N. C.: U. S. Public Health Service, 1968.

Willis, Byron H., The Hackensack Meadowlands Air Pollution Study, Summary Report, Research Triangle Park, N.C.: U.S. Environmental Protection Agency, July, 1973.

Willis, Byron H., The Hackensack Meadowlands Air Pollution Study; Task 3 Report: The Evaluation and Ranking of Land Use Plans, Research Triangle Park, N.C.: U.S. Environmental Protection Agency, November, 1973.

Willis, B. H., J. R. Mahoney and J. C. Goodrich, The Hackensack Meadowlands Air Pollution Study; Task 4 Report: Air Quality Impact of Land Use Planning, Research Triangle Park, N.C.: U.S. Environmental Protection Agency, July, 1973.

Willis, Byron N., John C. Goodrich and E. C. Reifenstein, "Incorporating Air Pollution Considerations in the Planning Process," Paper Presented at the Annual Meeting of The American Institute of Planners, San Francisco, Ca.: October 24-28, 1971.

Yocom, J. E., D. A. Chisholm, G. F. Collins, J. A. Farrow, R. A. Gagosz and J. C. Magyar, Summary Report: Air Pollution Study of the Capitol Region, Hartford, Conn: TRC Service Corp., 1967.